NMRA DCC Reference Manual *for* QSI Quantum® Q1a and Q2 Equipped Locomotives

Version 4.4.0
For Firmware Version 7
23 September 2008

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Digital Command Control Explained

Digital Command Control (DCC) is the standard adopted by the National Model Railroad Association (NMRA) in 1994[1] to allow compatible operation of all locomotives and Command Stations regardless of manufacturer.

DCC differs from Analog control in that DCC applies full voltage to the track at all times and controls the speed and functions of different locomotives by addressing each locomotive separately using assigned locomotive ID numbers. Because each locomotive can be addressed separately, you can independently control speed, lights, and sounds on different locomotives on the same powered track.

DCC provides features and opportunities that are usually not available under conventional Analog Control[2], but does require you to commit to a new and more complex operating system.

All Quantum equipped locomotives operate using NMRA DCC control. The three most common locomotives are Steam, Diesel and Electric, although others, such as trolleys, powered commuter cars, subways, etc. can be operated under DCC as well.

Quantum equipped locomotives have been designed to operate directly out of the box under NMRA standards for either conventional Analog DC operation or Digital Command Control. There are no switches in the locomotive that need to be set to select the type of control system. The Quantum System responds directly to the type of signal on the track.

1 The Electrical and Communication Standards were adopted by the NRMA in Portland OR in July, 1994. The basic Recommended Practices (RP's) were accepted in 1995 in Atlanta Georgia and the Service Mode RP's were established in 1996.

2 Quantum systems use an advanced Analog control system called QARC™ (Quantum Analog Remote Control) Technology that does provide many of the same features available in DCC. See the Quantum Analog Reference Manual for details.

This Manual

This manual is divided into seven parts:

- The first section summarizes how to operate your Quantum locomotive in DCC. Read this and you will quickly have your locomotive up and running.
- The second section summarizes the programming of Configuration Variables (CV's). Read this when you are ready to customize your locomotive's operation.
- The third section describes in detail NMRA standard CV's supported by Quantum locomotives. Skim over this to get a general idea of what it contains. You will often refer to it when you want to solve a particular problem.
- The fourth section outlines in excruciating detail the NMRA standard CV's which assign outputs to function keys. Normally you do not have to be concerned with these CV's, but sometimes this section is important, for example if you ever have to configure your locomotive to operate with a DCC controller having a small number of function keys.
- The fifth section describes in detail CV's that are unique to Quantum locomotives. Skim over this to get an idea of the degree of flexibility built into Quantum locomotives. Refer to this section whenever you want to customize volume levels, change the features that are assigned to function key outputs, configure the behavior of these features, or tweak your locomotive's running performance.
- The sixth section describes in detail additional NMRA standard CV's that you may find useful if you want to fine-tune your locomotive's running performance.
- The appendices describe operation with different DCC Digital Command Stations, troubleshooting and Applications Notes.

Most operations of Quantum equipped locomotives, such as turning the Bell on and off, changing direction, blowing a Horn or a Whistle, are the same across all locomotive types. Special operations for different types of Quantum equipped locomotives are described in the Operation Manuals that come with the locomotives. Any special features included in this Reference Manual will be described in sidebars or notes.

Please Note

This reference manual completely describes all features currently available in DCC when operating a Quantum locomotive that has Q1a or Q2 Version 7 firmware. If your locomotive has Version 6 or earlier firmware, use the Quantum DCC Reference Manual Version 3. To determine you software version read the contents of CV 7 (In Ops Mode, set CV 64 to 7 and hear verbal response).

Many of the new features described in version 4.1 of this manual are currently available only with Q2 firmware supporting O-Scale and G-Scale locomotives and with Q2 Quantum Revolution firmware.

As new Quantum locomotives are introduced, they may have features not found in earlier locomotives. Check the Operation Manual that came with your locomotive to determine which features apply to your locomotive. This document will evolve over time as new information is added to keep it as complete and current as possible.

Although reading the first section, "Locomotive Operation in DCC", will allow you to begin operating your Quantum locomotive immediately, the purpose of this manual is not to teach you how to use DCC. We assume that you already have the working knowledge and experience to operate the different DCC features and program CV's. If you are just getting started in DCC, there are several books listed in the appendices to instruct you in the operation of DCC layouts, turnouts, accessories, programming Configuration Variables (CV's), etc.

1 Locomotive Operation in DCC

1.1 Getting Started

Although DCC operation can be very complex, it does not have to be. Your Quantum locomotive is factory configured to operate the common and more popular features. The following brief instructions will get you up and running quickly.

To start operating your Quantum equipped locomotive immediately:

1) Select locomotive number 3

2) Set your controller to 128 (preferred) or 28 (acceptable) speed step range[3]

3) Start your locomotive by turning up the throttle

1.2 Basic Throttle and Direction Control

When you turn up the throttle, the locomotive starts moving and produces sounds appropriate to its moving state. The Headlight, Mars Light, and Reverse Light change intensity depending on the direction of movement.

When you reduce the throttle setting to zero, the locomotive comes to a complete stop and automatically enters Neutral. You will hear special background sounds appropriate to its resting state. If the locomotive was moving Forward, the Headlight (or operating Mars Light) dims when it stops and enters Neutral. This was common practice for prototype locomotives under Rule 17[4]. You will hear a Short Air Let-off whenever the locomotive enters Neutral.

If you leave your Steam locomotive in Neutral for at least 25 seconds and then slowly turn up the throttle, the locomotive plays Cylinder Cocks sounds as it starts moving. The Cylinder Cocks sounds automatically terminate after 16 repetitions or when the locomotive reaches a speed greater than 12 smph.

The direction of your locomotive changes when you press the direction key. If the locomotive was moving at the time you pressed the direction button, the locomotive slows at a speed determined by the deceleration setting in CV 4, come to a complete stop and then accelerates in the other direction as determined by the CV 3 acceleration setting. CV 3 and CV 4 are described in the section “Programming Configuration Variables”.

Locomotive Directional States

Quantum locomotives have four distinct Directional States:

Forward (FWD): If the locomotive is set to the Forward Direction and is moving, it is in the “Forward” state.

Neutral from Forward (NFF): If the locomotive is set to the Forward Direction, and the throttle is turned down to zero speed step and the locomotive is stopped, it will be in a Neutral State called “Neutral from Forward”.

Reverse (REV): If the locomotive is set to the Reverse Direction and is moving, it is in the “Reverse” state.

Neutral from Reverse (NFR): If the locomotive is set to the Reverse Direction, and the throttle is turned down to zero speed step and the locomotive is stopped, it will be in a Neutral State called “Neutral from Reverse”.

3 If you set your controller to 14 speed-step operation without reconfiguring your Quantum system to the same speed steps in CV 29, your Directional Lighting will not operate correctly.

4 Rule 17, followed by prototype railroads, states: The headlight will be displayed to the front of every train by night, but must be dimmed or concealed when a train turns out to meet another and the entire train has stopped clear of main track, or is standing to meet trains at the end of double track or at junctions.

1.3 Throttle Control Modes

There are four ways your locomotive can respond to your throttle.

- **Standard Throttle Control (STC)** :: Under STC, the percentage of full power applied to the motor is directly related to the throttle setting (speed step). Since the power to the motor is constant for a given throttle setting, the locomotive's speed varies depending on the load. The locomotive may easily stall at low speeds from minor gear binding, turnouts, and curves.
- **Calibrated Speed Control (CSC)**: Under CSC, the power applied to the motor is varied to maintain constant speed regardless of varying load conditions. The throttle setting (using 128 speed steps specifies the locomotive's speed in 1 smph (scale miles per hour) increments. If your throttle is set at 35, the locomotive tries to maintain 35 smph on level track, up hill, and down hill. If locomotives in a consist differ even slightly in speed calibration, some of the locomotives do all the work while the other locomotives are dragged along.
- **Load Compensated BEMF Speed Control (BEMFSC):** Under BEMFSC, each speed step corresponds to a target BEMF value. The locomotive adjusts the power applied to the motor so that the locomotive's measured BEMF matches the target BEMF.
- **Regulated Throttle Control (RTC)** RTC combines the best of STC and Speed Control. It is the preferred method when multiple heading Quantum locomotives together because it automatically equalizes power between locomotives. Like Speed Control, RTC allows you to run your locomotive at very slow speeds without concern that it will abruptly stop from minor impediments such as misaligned track joints, tight curves, or rough switches. RTC operates your locomotive as though it has huge mass; your locomotive will resist changes in speed once it is moving and will resist starting up quickly if at rest.

For further explanation of these four modes, see CV 56.4: QSI Throttle Mode.

The default mode is RTC. You can change to STC using CV 56.4.

Quantum equipped locomotives will produce labored sounds under acceleration and lighter non-labored sounds under deceleration. The level of labored sounds is proportional to the value of CV 3 plus CV23, and of CV 4 plus CV24 and how much the throttle is increased or decreased. Diesel locomotives produce louder motor sounds under acceleration and softer motor sounds under deceleration. Steam locomotives produce louder chuffs under acceleration and softer chuffs under deceleration.

Important Legal Notice

BEMF Speed Control and Calibrated Speed Control under DCC operation are not included in your Q1a or Q2 equipped locomotive model. These functions have been declined by model railroad importers of Quantum equipped locomotives because of threats of litigation by Mike's Train House. QSI believes the claim by Mikes Train House is unfounded because these control features were developed by QSI and others and were in use long before Mike's Train House claims to have invented them. QSI does not believe that Quantum Sound System infringes any MTH patent.

1.5 Function Keys

Quantum decoders support the 0-12 Function Key standard as now accepted by the NMRA; the old 0-8 standard is not supported.

1.5.1 Common Feature Function Key Assignments

The following table lists features that have been pre-assigned to your DCC Function Keys for common operation across the different types of Quantum locomotives. Check the Operation Manual that comes with your locomotive to see which of these common features are offered or what additional custom features have been included.

These common features are described in detail in the following sections.

Notice that some keys operate different features in Forward/Reverse than in Neutral.

F-Key	FWD/REV	NFF/NFR
FL(f)[5]	Headlight,, Reverse Light, and Hazard Light Directional Lighting	Headlight, Reverse Light, and Hazard Light Directional Lighting
FL(r)[6]	Headlight, Reverse Light, and Hazard Light Directional Lighting	Headlight, Reverse Light, and Hazard Light Directional Lighting
F1	Bell on/off (if assigned[7])	Bell on/off (if assigned)
F2	Horn/Whistle w/ Doppler Shift	Horn/Whistle
F3	Coupler Crash/Coupler Fire	Coupler Arm (Enable) or Coupler Fire
F4	Steam Blower Hiss/ Diesel Fans and Louvers/ Electric Cooling Fans	Steam Blower Hiss/ Diesel Fans and Louvers/ Electric Cooling Fans
F5	Dynamic Brakes	Dynamic Brakes
F6	Doppler Shift	Locomotive Start Up
F7	Squealing Brakes/Flanges and Air Brakes	Steam Cylinder Cocks Arm Diesel Long Air Let-off Electric Long Air Let-off Gas Turbine/Diesel Transition
F8	Audio Mute	Audio Mute
F9	Heavy Load[8]	Shut Down[9]: Disconnect-Standby-Total Shut Down
F10	Status Report (SMPH)	Status Report (ID's, etc.)
F11	Alternate Horn Selection Number Board or Marker Lights on/off	Alternate Horn Selection/ Number Board or Marker Lights on/off
F12	Automatic Cab Lights	Automatic Cab Lights

5 The FL Key is labeled "F0", "Headlights" "Lights" or "Directional Lighting" on some DCC controllers.
6 FL(f) and FL(r) activate/deactivate the automatic behavior of the Headlight, Reverse Light, and Hazard Directional Lighting regardless of which direction the train is moving.
7 If the prototype did not have a bell, the bell feature is not assigned to F1 and no other feature is assigned in its place.
8 Early Q1 BLI and Lionel locomotives used F9 for Cruise Control, which was only available on locomotives equipped with Speed Control.
9 There are three stages to Shut Down. You double click the F9 key to advance to each stage.

1.6 Automatic Features

Automatic Quantum Features depend on the directional state of the locomotive. Automatic Control can be enabled or disabled by their indicated function keys. The state of each Automatic feature in each direction is shown in the table below for all locomotive types including steam, diesel and electric.

Feature	Function Key	Forward	Neutral from Forward	Reverse	Neutral from Reverse
Headlight	F0 or FL	Bright	Dim[10]	Dim	Dim
Rear Tender Light	F0 or FL	Dim[11]	Dim	Bright	Dim
Mars Light	F0 or FL	Strobing	Steady On	Steady On	Steady On
Ditch Lights	F0 or FL	On	Off	Off	Off
Number Board Lights	F11	On	On	On	On
Marker Lights	F11	On	On	On	On
Cab Lights	F12	Off after 15 seconds	On after 10 seconds.	Off after 15 seconds	On after 10 seconds.
Steam Blowers	F4	Off after 10 seconds.	On after 10 seconds.	Off after 10 seconds.	On after 10 seconds.
Vents & Cooling Fans	F4	On after 20 seconds.	Off after 10 seconds.	On After 20 seconds.	Off after 10 seconds.
Cylinder Cocks[12]	F7	If armed, plays Cylinder Cocks for 16 times or until speed exceeds 12 smph.	Cylinder Cocks armed after 25 seconds.	If armed, plays Cylinder Cocks for 16 times or until speed exceeds 12 smph.	Cylinder Cocks armed after 25 seconds.

When an indicated function key enables an "automatic" light feature, the associated lights operate according to the states shown in the table. For instance, enabling the Automatic Mars Light in Neutral will not cause the Mars Light to strobe since their automatic behavior would have them at a steady-on setting in that directional state; however, it you then entered Forward, the Mars Light would begin to strobe. When an indicated function key disables an "automatic" feature, all lights will be off. For instance, disabling the "Automatic Mars Light" will immediately shut off the Mars Light in any direction and they will not turn on again until the automatic feature is enabled.

Note: Use CV 55 to change the behavior of lights from what is shown in the above table and description.

Note: Not all automatic features may be included in your locomotive model.

Note: Lights and other features can be assigned to function keys and configured to different kinds of operation and initial conditions in CV 53 (Output Feature Assignment) and CV 55 (QSI Feature Configuration). See the Quantum DCC Reference Manual, version 4.

Note: Cylinder Cocks can also be armed in Neutral with the F7 key or the F6 Start Up key without having to wait for the 25 time out period.

Note: The start up state for directional lighting is "activated". See CV 55 for further information.

Note: Most steam locomotives use a steam-powered generator, called a Dynamo, to supply electricity to the lights. When the lighting system is turned on, the brightness of the headlight increases slowly as the steam generator revs up to full power. Check your Operation Manual to see if your steam model has a Dynamo.

Note: If your FL key does not predictably affect the Headlight or Reverse Light, see the troubleshooting section in the appendices.

10 If your locomotive has the Mars Light, the Headlight will be off (instead of "Dim") in all states except Forward where it will be Bright.
11 Most Quantum 1 and Q1a Reverse Lights cannot be dimmed; they only have bright and off settings. In these cases, "Dim" is equivalent to "Off".
12 Cylinder Cocks arming after Start Up and/or after 25 seconds in Neutral can be set using CV 51.2. The settings in this CV apply to both Analog and DCC operation.

1.7 Horn/Whistle and Bell Buttons (F2 Key and F1 Key)

Some DCC controllers have separate horn/whistle and bell buttons, in addition to Function Keys assigned to horn/whistle and bell operation. The bell is usually assigned to F1, and the horn is usually assigned to F2.

The F2 key behaves differently than the Horn button.

- Pressing F2 and releasing it will cause the horn/whistle to come on and stay on until you press F2 again.
- Pressing the Horn button will blow the horn/whistle only as long as you hold the button down.

There is no difference in operation between the Bell button and its corresponding function key. Pressing F1 and releasing it will cause the bell to come on and stay on until you press F1 again.

Horns and whistles have start up and shut down effects and a short hoot record for short duration horn/whistle blasts. Some models have an additional fancy ending (playing the horn/whistle). On these models, you can activate the fancy ending by tapping the horn button at the end of the horn blast.

If your locomotive is equipped with Ditch Lights, they will automatically strobe when the horn is being blown, and will continue to strobe until five seconds after the horn signal has stopped[13].

With Diesel, Electric, and Gas Turbine models, since the prototype horn uses compressed air, you will hear Air Pump sounds turn on after the Horn is operated.

Note: If your DCC controller has assigned the Bell to F3, you can reassign your Quantum decoder's F3 to the bell output (see CV 37). Remember to reassign the F1 Function to some other output besides 3 (see CV 35).

1.8 Coupler and Coupler Crash Sounds (F3 Key)

There are two ways to use the F3 key.

1) In Forward or Reverse, as your locomotive is moving to couple up to a string of cars, press F3 to trigger the crashing sound of a locomotive coupling. Press F3 again as the locomotive is moving out to produce the same sound as the slack is taken up in the cars.
2) Press F3 in Neutral to produce uncoupling sounds as you disconnect cars over uncoupler magnets. Press F3 once to produce the sound of the lift bar and coupling pin being raised. This first press also arms the uncoupling sound effect. Press F3 again while moving or in Neutral to produce the sound of the coupler knuckle opening and the air-lines parting.

If you armed the Coupler in Neutral and your locomotive is now in Forward or Reverse, pressing F3 produces the sound of the coupler opening. Thereafter, as the locomotive continues in Forward or Reverse, pressing F3 will produce coupler crash sounds.

13 The hold time for strobing Ditch Lights after the horn button is released can be set in CV 55.84.5.

1.9 Sound-of-Power™

If CV 3, or CV 23 and CV 4, or CV 24 has been set to non-zero positive values, your locomotive will produce additional labored engine sounds under acceleration and lighter engine sounds under deceleration. The level of labored sounds is proportional to the values for these four CV's, and how much the throttle is increased or decreased. Laboring is different for the three primary types of locomotives:

Diesel Motor RPM: Quantum has all eight diesel-motor throttle "notches" found on prototype locomotives. As you increase the throttle, you will hear the RPM's increase for every increase in ten speed steps (at 128 speed step setting). Idle is considered Notch 0 and occurs for speed step 0. Notch 1 ranges from 1 to 10, Notch 2 from 11 to 20, Notch 3 from 21 to 30, etc. If your controller has an option to increment or decrement your throttle set setting by ten speed steps, it is very easy and predicable to set your notch value.

Steam Exhaust: Under acceleration the steam exhaust is labored and loud and under decelerating, the steam exhaust is lighter. Also, when starting out after an extended period in Neutral (over 25 seconds), you will hear steam and water vented from the Cylinder Cocks when it starts out. The Cylinder Cocks will vent 16 times or until speed exceeds 12 smph.

Electric Traction Motors: Under acceleration, hear the traction motors rev up and strain as the Electric locomotive gains full speed. Under deceleration, the traction motors are not labored and rev down as the locomotive slows.

1.10 Dynamic Brakes (F5 Key)

Diesel Locomotives: The prototype Dynamic Brakes, found on most diesels, cause the train to slow down by using the traction motors in generator mode. This helps dissipate the energy of a moving train by applying electrical power from the traction motors to a large air-cooled resistor load in the locomotive. These resistor grids can get quite hot and require cooling by fans located on the roofs of the locomotives.

- Pressing F5 in Forward/Reverse will set the Diesel Motor sound to idle at the lowest Sound of Power setting and turn on the powerful Dynamic Brake Cooling Fans.
- Pressing F5 in Neutral does not turn the Dynamic Brake Fans on unless the locomotive is in Disconnect (see F9 "Disconnect" below).

Electric Locomotives: Early Electric locomotives did not have Dynamic Brakes. However, the Dynamic Brake function has been included to make Electric locomotives consistent with other Quantum equipped locomotives.

- Pressing F5 in Forward/Reverse will set the Electric Traction Motor Sound-of-Power to the lowest setting allowing these early Electric locomotives to behave consistently[14] with other locomotives that do have Dynamic Brake sounds in multiple unit Consists.
- If an Electric locomotive does have Dynamic Brakes with resistor grids and cooling fans, the locomotive will behave in a similar manner to Diesels.

Steam Locomotives: Prototype Steam locomotives do not have Dynamic Brake sounds. However, the Dynamic Brake function has been included to make Steam locomotives consistent with other Quantum equipped locomotives.

- Pressing F5 in Forward/Reverse will set the Steam Exhaust Sound-of-Power to the lowest setting allowing the Steam locomotive to behave consistently[15] with other locomotives that do have Dynamic Brake sounds in multiple unit Consists.

The Dynamic Brakes feature automatically turns off when entering or leaving Neutral, or the speed of the locomotive drops below 8 smph, or if the throttle is turned up. The Dynamic Brakes cannot be turned on in Forward or Reverse unless the locomotive is traveling over 9 smph.

14 It would be inconsistent for the Electric Locomotive to be working at full Sound-of-Power while brakes are being applied in other locomotives within the same consist.
15 It would be inconsistent for the Steam Locomotives to be working at full Sound-of-Power while brakes are being applied in other locomotives within the same consist.

1.11 Doppler Shift (F6 in Forward and Reverse)

There are two ways to initiate the Doppler Shift effect.

1.11.1 Horn Button Method[16]

1) If your controller has a horn button in addition to the F2 key, press the horn button to turn on the Horn/Whistle while the locomotive is moving towards you.
2) Wait at least one second while the Horn/Whistle is blowing
3) Release and re-press the horn button quickly so the Horn/Whistle does not shut off. You will hear the Horn/Whistle and other locomotive sounds increase in volume and shift in pitch as the locomotive passes by and then reduce in volume.
4) Release the horn button or continue blowing long and short blasts. Five to seven seconds after releasing the horn button, the sounds will gradually return to normal.

1.11.2 F6 Doppler Shift Operation Method

1) Start the Horn/Whistle by pressing and releasing the F2 key.
2) Press F6 as the locomotive is moving towards you. The Horn/Whistle and other locomotive sounds increase in volume and shift in pitch as the locomotive passes by and then reduce in volume.
3) Press F2 button again to shut off the Horn/Whistle or continue blowing long and short blasts by pressing and re-pressing F2. If you shut off the Horn/Whistle for more than five to seven seconds, the sounds will gradually return to normal.

If the bell was on during DopplerShift, it will automatically turn off prior to the sounds returning to normal.

If Doppler Shift is initiated without the Horn/Whistle blowing, the sounds return to normal soon after the Doppler Shift is finished.

Doppler Shift is speed dependent. The greater the speed, the greater the amount of pitch change as the locomotive passes by. There is no Doppler Shift at speeds less than 15 scale miles per hour (smph); instead you will hear a short air let-off when F6 is pressed.

Try using the F6 key to affect chuffing sounds (sans Whistle or Bell) to create interesting environmental effects.

Note: Some base stations produce an intermittent and independent horn signal interruption that causes an unexpected Doppler Shift. If this happens frequently, you may want to disable the horn triggered Doppler Shift by setting CV 51.2 bit 0 to 0.

Note: With some Command Stations, using the horn button to activate the Horn/Whistle, and then while this button is held down, pressing F6 causes the Horn/Whistle to shut off instead of causing a Doppler Shift effect.

[16] This is similar to the method used in Analog DC to trigger a Doppler Shift.

1.12 Squealing Brakes and Flanges (F7 in Forward or Reverse)

Quantum locomotives provide automatic Brake Squeal as a locomotive slows to a stop. To enable automatic Squealing Brakes operate the locomotive over 40 smph (64 skph). When the speed is reduced to less than 20 smph (32 skph), squealing Brake sounds will sound automatically.

When the locomotive is moving, you can also manually activate continuous or variable brake sounds when slowing or stopping the locomotive or to simulate the sounds of squealing flanges on curved track.

1) Press F7 to start Squealing Brake sounds.
2) The Squealing Brakes sounds end automatically, but you can press F7 while the brake squeal is occurring to re-trigger the squealing sounds. This allows you to continue the squealing brake sounds without any dead period for an indefinite period.

The squealing brake sounds will terminate abruptly when the locomotive stops and enters Neutral.

Note: If you lower the throttle to speed step 0, pressing F7 will apply Air Brakes instead of activating squealing brake sounds.

1.13 Air Brakes (F7 in Forward or Reverse)

If you have selected any non-zero deceleration inertia value in CV 4 and/or CV 24, the F7 key can be used to apply Air Brakes to stop the locomotive more quickly than it would normally stop from the inertia settings [17]. To use Air Brakes:

- Turn the throttle down to speed step 0 on a moving locomotive; this enables the F7 key to act as a brake.
- Press the F7 key. Hear a brief brake squeal sound and air being released from the brake lines continually. The longer the air is released the greater the braking action.
- Press the F7 key again to stop the air release. The train will continue to slow at the last braking value.

  Note: F7 will apply brakes when set to1 and stop the air release when set to 0. Depending on the initial setting for F7 when you turn your throttle down to speed step zero, you may need to press the F7 key twice to first apply brakes.
- If you want to apply more braking, press the F7 key again to release more air. When you reach the desired amount of braking, press F7 again to stop the air release.
- Turn up the throttle to any value above 0 to release the brakes; this action resets the locomotive's deceleration to a value determined by the sum of CV 4 and CV 24.
- If the locomotive is in Neutral when the F7 key is pressed, the Cylinder Cocks will arm.[18]

Note: If the throttle is set to any speed step except 0, Air Brakes are not enabled; instead the F7 key will now manually activate Squealing Brake/Flange sounds but will not affect the locomotive's deceleration.

Note: If the direction state is changed while moving, F7 is enabled to act as a brake without the need to reduce the throttle to speed step 0. After stopping and changing direction, the loco will accelerate back to its original speed. If CV 4 or CV 24 is non-zero, F7 can be used to apply Air Brakes to stop a moving locomotive more quickly than it would normally stop from the inertia settings[19].

17 CV 4 and CV 24 determine the deceleration rate. Applying the brakes increases the deceleration rate temporarily.
18 If the optional Cylinder Cocks feature is not include in your model, the F7 key will produce a long Air Let-off.
19 CV 4 and CV 24 determine the deceleration rate. Applying the brakes temporarily increases the rate of deceleration.

1.14 Audio Mute (F8 Key)

You can reduce the System Volume to a lower level or increase it back to its original setting using the F8 key. This is useful when you need to reduce the sound to engage in a conversation or to answer the phone.

1) Set F8 to “1”. All sounds, including the Whistle, Bells, Motors and Chuff will gradually go off.
2) Set F8 to “0”. All sounds, including the Whistle, Bells, Motors and Chuff will gradually return to normal volume.

If you have many locomotives operating at once, you can reduce the volume on all those that are running in the back of the layout and increase the volume of the closest locomotive. The Mute feature changes the sound gradually over a couple of seconds, which allows the sound to increase or decrease realistically as the locomotive approaches or recedes from the observer.

The Mute state is not retained if track power is turned off. On power up the locomotive returns to full system volume.

Note: You can set the Mute volume in CV 51.1 if you want to be able to quickly quiet your locomotive without having the sounds turn completely off.

1.15 Heavy Load (F9 in Forward or Reverse)

Heavy Load is applied while the train is moving; it maintains the train at a nearly steady speed while allowing you to have control over the sound effects of a working locomotive. Heavy Load represents a train that would take over ten minutes to accelerate to full speed or to bring to a complete stop. It is independent of any inertia values set in CV3, 4, 23, or 24.

Under Heavy Load, changing the throttle will have little affect on the locomotive’s speed. Instead you use the throttle to control Sound-of-Power effects. When you approach a grade under Heavy Load, increase the throttle and hear the locomotive produce heavy laboring sounds. When the locomotive goes down a grade, reduce the throttle to hear the locomotive drop to light laboring sounds. You control labored sounds by how much the throttle is increased or decreased from its initial position (where Heavy Load was turned on).

1) Press F9 and hear one short hoot when Heavy Load is turned on[20]. You can apply Heavy Load as soon as you start moving, or wait until you are up to speed.
2) Press F9 and hear two short hoots when Heavy Load is turned off. Before turning Heavy Load off, return the throttle to its initial setting (where Heavy Load was turned on) to avoid sudden acceleration or deceleration.

Heavy Load can only be turned on or off in Forward or Reverse[21]. If turned on, it will remain on in Neutral. If you want it off when you start out from Neutral, turn it off immediately after increasing the throttle.

Heavy Load is automatically turned off when track power is turned off.

Under RTC and Heavy Load, grades, tight curves or other real loading effects, will have little effect on the speed of the train. But under STC and Heavy Load, grades, curves, loading, etc. will affect the train speed.

[20] This feedback can be disabled via CV51.2 bit 3.

[21] You can turn Heavy Load on and off in Neutral if you set CV53.x.1 to 179, the Heavy Load feature ID.

1.16 Status Report (F10)

Quantum locomotives provide verbal information about a locomotive's current operating state when the locomotive is in Neutral or the locomotive's current speed when the locomotive is moving.

- Press F10 in Neutral; the locomotive will verbally report first its currently enabled long or short DCC address followed by its consist ID if it has one, followed by its Shut Down state (Disconnect, Standby or Shut Down).
- Press F10 in Forward or Reverse; the locomotive will verbally report the locomotive's speed in scale miles per hour (smph) or scale kilometers per hour (skph). (You can select between scale miles per hour (smph) or scale kilometers per hour (skph) in CV56.0.)

Note: When a Status Report or Verbal Speedometer Readout begins, the locomotive's sounds will reduce to one half their current volume settings. Locomotive sounds return to normal volume when the report has ended.

Note: The Status Report in Forward and Reverse can be configured to also report the Back EMF value and/or motor Pulse Width Modulation (PWM) value. See CV 55.178.0.

Note: In a consist, all locomotives will simultaneously report their status when the F10 key is pressed unless disabled in CV 22.

1.17 Alternate Horn Selection (F11)

Some prototype steam locomotives had both a steam whistle and an air horn. The whistles worked best in areas where it was necessary for the sound to carry a long way, while the horn was more useful in the city or fogy areas where it was easier to tell the location of the locomotive by its higher pitched sound. Some diesels and electric locomotives used two horns for similar reasons. The Alternate Horn Selection key allows you to choose between two Horn sounds on selected diesel or electric locomotives or between a Whistle and a Horn on steam locomotives.

- Press the Alternate Horn Selection key, F11, to select between the alternate Horn and the primary Horn or the Whistle. Hear a short hoot to indicate which one has been selected.
- Operate the selected Horn or Whistle with the F2 key.

Note: The feedback hoots can be disabled/enabled in CV51.2.

Note: Setting F11 to "1" selects the primary Horn or the Whistle. Setting F11 to "0" selects the alternate Horn.

1.18 Three Stages of Shut Down: Disconnect, Standby and Total Shut Down (F9 in Neutral)

Locomotive Shut Down has three distinct stages, each entered by double-clicking or double-pressing the F9 Key[22].

Stage One: Disconnect

1) In Neutral, double-press F9 to enter Disconnect. You will hear a Long Air Let-off, which represents the pneumatic reverse lever on a Steam locomotive being placed in the Neutral position or the Diesel transition level being placed in the off or disconnect position. Your locomotive's motor drive is disconnected.
2) To leave Disconnect, either double-press the F6 Start Up key as described in the Start Up section or double-press F9 again to reach the next stage of Shut Down, Standby.

A locomotive in Disconnect continues to respond to all function keys.

For a Diesel locomotive in Disconnect, if the throttle is increased or decreased, the motor sounds will rev up and down but the locomotive will not move. If the Dynamic Brakes are activated, the motors sounds will be labored under Sound of Power control as the throttle is increased and decreased. Prototype Diesel Motor/Generator power output is often tested under Dynamic Brake load in disconnect.

For an Electric locomotive in Disconnect, there is no action or sound associated with moving the throttle up and down and no affect from having the Dynamic Brakes activated.

For a Steam locomotive in Disconnect, if the throttle is increased/decreased, the hissing sound of venting steam will get louder/softer but the locomotive will not move. Prototype Steam locomotives would sometimes vent steam in Neutral to clear rust debris from the super-heaters that can affect the throttle.

Stage Two: Standby

1) In Disconnect, double press F9 to enter Standby. You will hear a Long Air Let-off followed by the Directional Lighting turning off. The motor will remain disconnected, while the Air Pumps, automatic Steam Blower/Cooling Fan operation, Number Board Lights and Cab Lights will continue to operate.
2) To leave Standby, either double-press the F6 Start Up key described in the Start Up section or double-press F9 again to reach the final stage of Shut Down, Total Shut Down.

In Standby, the locomotive will not respond to the throttle or most function keys[23]. The three exceptions are the F6 Start Up Function Key (described below), the F8 Mute Key (described above) and the F10 Status Key (described above).

Standby in Diesel locomotives, called Low Idle, has more utility than Standby in Steam and Electric locomotives. It allows a Diesel to be left on a siding inactive with only the motor running at its special "Low Idle" sounds. For Steam and Electric locomotives, the locomotive will appear to be completely inactive except for Cab and Number Board lights, occasional Air Pump sounds, and Blower or Fan sounds.

Stage Three: Total Shut Down

1) In Standby, double-press F9 to enter Total Shut Down. You will hear a Long Air Let-off followed by the sounds of a shutdown procedure specific to your type of locomotive.

   Diesel Locomotives: Low Idle Diesel Motors will return to normal idle sounds. Then the Air Pumps will turn off, as will the Number Board Lights, followed by the sounds of the Cooling Fans shutting off, the Louvers closing, the Diesel Motor(s) shutting down, Cab Lights shutting off, and finally the engineer's door opening and shutting.

   Electric Locomotives: The Air Pumps will turn off, Cab Lights will turn off, followed by the sounds of the Louvers being closed and the engineer's door being opened and shut.

   Steam Locomotives: The Air Pumps will turn off, followed by the sounds of Pop Off operating for about ten seconds, the Cab Lights shutting off, and finally the Blower Hiss will die out.

2) To leave Total Shut Down, double-press the F6 key.

---

22 Double-clicking ensures that Shut Down stages are not entered or exited accidentally. Doubling-pressing is defined as two F9 presses within two seconds. Note that the F9 key may have to be pressed three times the first time you use it due to the command station and locomotive having different initial states for F9.

23 Pressing a Function Key will only produce a Short Air Let-off.

In Total Shut Down, the locomotive will not respond to any function keys except the F6 Start Up Function Key (described below) and the F10 Status Key (described above).

Total Shut Down allows you to take a locomotive “off-line” (turn off sounds, lights, ignore throttle and function commands (except turn on)) independent of the operating session; that is, the locomotive will still be “off line” when power is reapplied for the next operating session.

If power is turned off at any stage of Shut Down (Disconnect, Standby or Total Shut Down) or during a Shut Down procedure, the locomotive will remember its last Shut Down stage, and will power up in that Shut Down stage.

If Start Up is initiated during any of the above Shut Down procedures, Shut Down is aborted and the locomotive returns to normal operation.

1.19 Start Up (F6in Neutral)

If your locomotive is in any of the Shut Down stages, you can return your locomotive to normal operation by double-pressing[24] the F6 Key. Start Up will be different for each stage of Shut Down, but always begins with a Long Air Let-off and ends by the locomotive entering normal operation[25].

Start Up from Disconnect

- Double press F6 in Disconnect, the locomotive will produce a Long Air Let-off and enter normal operation.

Start Up from Standby

- Double press F6 in Standby, the locomotive will produce a Long Air Let-off, the Directional Lighting will turn on and then the locomotive will enter normal operation.

Start Up from Total Shut Down

- Double press F6 in Total Shut Down; the locomotive will produce a Long Air Let-off, and begin a full start up procedure.

  Diesel Locomotives: The Long Air Let-off is followed by the sound of the engineer's door opening and closing. Cab Lights turn on, Number Boards come on, and Directional Lighting turns on. Then the Vents open and Fans start up, the Diesel Motor or Motors start up, the Air Pumps turn on, and finally the locomotive enters normal operation.

  Electric Locomotives: The Long Air Let-off is followed by the sound of the engineer's door opening and closing. Cab Lights turn on, Number Boards and Marker Lights turn on, and Directional Lighting turns on. Then the Vents open and Fans start up, the Air Pumps turn on, and finally the locomotive enters normal operation.

  Steam Locomotives: After the Long Air Let-off, the Dynamo revs up and the Directional Lighting turns on. Then Cab Lights turn on, followed by the Air Pumps and the Steam Blower turning on, and finally the locomotive enters normal operation.

During the Start Up from Total Shut Down procedure, a Quantum locomotive will not respond to any function key. However, if the throttle is turned up, the Start Up procedure abruptly terminates and the locomotive immediately enters normal operation.

Note: Whenever a locomotive receives a Start Up command, regardless of whether the locomotive is in a Shut Down stage or operating normally, the locomotive will restore all automatic operations and return all feature function states to their initial states as specified in CV55.

Note: Whenever F6 Start Up key is double-pressed in Neutral for a steam locomotive, the Cylinder Cocks[26] will be armed. Cylinder Cocks sounds will play when the throttle is turned up to leave Neutral.

1.20 Function Key Operation in Neutral

Some function keys used in Forward and Reverse will have different effects when used in Neutral:

- Pressing F6 results in Doppler shift for a moving locomotive but activates Start Up in Neutral.
- The F7 key produces Squealing Brake Sounds or applies brakes for a moving locomotive but produces a Long Air Let-off in Neutral in Diesels or enables Cylinder Cocks in Steam locomotives.
- Pressing F9 turns on/off the Heavy Load feature in a moving locomotive but activates Shut Down in Neutral.

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24 Double-pressing ensures that Start Up is not entered or exited accidentally. Doubling-pressing is defined as two F6 presses within two seconds. Note that the F6 Key may have to be pressed three times the first time you use it due to the command station and locomotive having different initial states for F6.

25 The locomotive enters Neutral with Long Air Let-off if speed step is zero. If speed step is non-zero, the locomotive will enter either forward or reverse.

26 Not all steam models have Cylinder Cocks feature.

2 Programming Configuration Variables

2.1 Service Mode Programming[27]

To perform Service Mode Programming, place your locomotive on an isolated track, called a Programming Track, that is electrically insulated from the main line and separately connected to a special output from your Command Station.

There are two advantages to programming in Service Mode.

1. On the Programming Track, no Locomotive Address is required to program your locomotive. This is important if you have forgotten your locomotive's ID numbers or have programmed them incorrectly. This is also why programming must be done on an isolated track section. Otherwise, CV's of all locomotives on your layout would be programmed with the same value.
2. On the Programming Track, the locomotive responds with Service Mode Acknowledgements to command station requests to verify the contents of a CV. In this way the command station is able to read back the current value of a CV. This is important if you want to change a CV by some amount but need to know it's current value before you enter a new value.

Some Command Stations restrict the amount of power that can be delivered to the Programming Track to prevent damage to improperly installed aftermarket decoders. If the decoder were wired correctly, the Programming Track would provide enough power to allow it to be programmed. If the decoder were wired incorrectly and a short circuit occurred, the limited current from the command station would not be enough to damage the decoder, allowing the operator another chance to wire it correctly.

To accommodate command stations that restrict power during Service Mode programming, the Quantum System reduces its power consumption to a minimum by shutting off all lights, sound and other operations during Service Mode operation. Even so, a Quantum Sound Decoder still requires more current than most non-sound decoders. If your Quantum System will not program with your particular command station, you may need to program on the Main (Ops Mode Programming). You can also purchase from Tony's Train Exchange®[28], a simple, inexpensive power booster (PowerPak™ by DCC Specialties) that will allow you to program on the program track with any DCC command station.

> **Note:** Some Command Stations will not operate Quantum Systems in Service Mode due to insufficient power output or timing problems. (Check the appendices for a listing of recommended command stations). If you cannot operate in Service Mode, use Ops Mode programming.

27 All four methods are supported: Address-Only Mode, Physical Register Addressing Mode, Paged CV Addressing Mode, and Direct CV Addressing Mode.

28 Tony's Train Exchange; 1-800-978-3472; info@ttx-dcc.com .

2.2 Operations Mode Programming[29]

Operations Mode Programming is also called Ops Mode Programming or Programming on the Main

In this programming mode, you do not move your locomotive to an isolated programming track. You program it in place on the Main track as you are operating it.

The Quantum System will allow you to program all CV's, including address CV's (CV 1, CV 17 and CV 18), in Operations Mode.

There are advantages and disadvantages to using Operations Mode Programming.

1) One disadvantage is that, in Ops Mode, Quantum decoders do not support any advanced acknowledgement mechanism, as defined by the NMRA. If you are using a command station that provides readout for your CV's in Ops Mode, it can only indicate which CV you are addressing and the value you want to program. You will not be able to determine what value is already entered in that CV or that the new value has been accepted and is correct.

   Note: In Ops Mode, Quantum locomotives do give verbal feedback during CV programming. If CV Verbal Acknowledgement is enabled (see CV 62), the CV number and its new value are announced over the locomotive's sound system when a CV is programmed.

   Note: In Ops Mode, you can command a Quantum locomotive to speak out the current value of any CV (see CV 64).

2) Another disadvantage with Programming on the Main is that you need to address your locomotive with its ID number in order to change its CV values. This could be a problem if you have forgotten your locomotive's ID number. Or you might use the wrong address and program the wrong locomotive. It could happen that you find yourself unable to communicate with your locomotive. If this does happen, you can move your locomotive to a Programming Track and change your locomotive's ID using Service Mode Programming. Or you can do a hardware reset by pulling the reset jumper on the circuit board or by using the Magnetic Wand[30],, which will set the locomotive's ID to short address 3 (See your locomotive's operating manual for further information on performing a hardware reset.).

   Note: Some command stations do not support programming address CV's on the main. See notes in trouble shooting and related CV's (1, 17, 18, 56.129) for possible solutions to this problem.

3) One advantage of programming on the main is that you often can observe an immediate change to your locomotive's behavior when you program a CV. For example, you can hear the System Volume or an individual feature sound volume change immediately after you program its new CV value. In Service Mode, you have to move the locomotive from the Service Mode Programming track to the Main track to see the effect of changing a CV.

29 Both the short form and the long form of the CV access instructions are supported.
30 A magnetically activated switch on the circuit board replaced the jumper on later Quantum equipped locomotives.

2.3 List of CV's Supported by Quantum Locomotives

The following table lists all CV's. The third column, labeled "NMRA", indicates whether these CV's are mandatory (M), recommended (R), or optional (O). The fourth column indicates if this CV is supported by QSI and the fifth column indicates the common default value.

CV#	CV Name	NMRA	QSI Supported	Default Value Decimal	Comment
1	Primary Address	M	Y	3	
2	V-Start	R	Y	32	This number may change from locomotive to locomotive.
3	Acceleration Rate	R	Y	0	
4	Deceleration Rate	R	Y	0	
5	V-High	O	Y	1	Either 1 or 0 in this CV will disable V-High
6	V-Mid	O	N	-	
7	Manufacturer Version No.	M	Y	-	See CV 56.254 and CV 56.255 for additional information on Quantum Version numbers.
8	Manufacturer's ID	M	Y	113	
9	Total PWM Period[31]	O	N	-	Not needed with our motor control
10	EMF Feedback Cutout2	O	N	-	Not needed with our BEMF detection.
11	Packet Time-Out Value	R	Y	1	
12	Power Source Conversion	O	N	-	
13	Analog Mode Function Status	O	N	-	
14	Reserved by NMRA for future use	-	-	-	
15	Reserved by NMRA for future use	-	-	-	
16	Reserved by NMRA for future use	-	-	-	
17	Extended Address	O	Y	0	CV 17 and 18 form a paired CV. CV 17 must be written first followed by CV 18
18	Extended Address	O	Y	0	See above.
19	Consist Address	O	Y	0	
20	Reserved by NMRA for future use	-	-	-	
21	Consist Address Active for F1-F8	O	Y	0	
22	Consist Address Active for FL and F9-F12	O	Y	0	
23	Acceleration Adjustment	O	Y	0	
24	Deceleration Adjustment	O	Y	0	
25	Speed Table Selection	O	Y	2	Linear
26	Reserved by NMRA for future use	-	-	-	
27	Reserved by NMRA for future use	-	-	-	
28	Reserved by NMRA for future use	-	-	-	
29	Configuration Data #1	M	Y	6	28 speed step mode. Power Source Conversion enabled.
30	Error Information	O	N	-	May be used in the future but not currently needed.
31	Configuration Data #2	O	N	-	Reserved by NMRA for future use.
32	Configuration Data #3	O	N	-	Reserved by NMRA for future use.
33	Output Location for FL(f)	O	Y	1	By default set to directional lighting.
34	Output Location for FL(r)	O	Y	3	By default set to directional lighting.
35	Output Location for F1	O	Y	4	By default set to bell output.
36	Output Location for F2	O	Y	8	By default set to whistle output.

31 Changes are not allowed. The PWM is already optimized for Quantum equipped locomotives.

37	Output Location for F3	O	Y	16	By default set to coupler sounds output.
38	Output Location for F4	O	Y	4	By default set to Cooling Fans output.
39	Output Location for F5	O	Y	8	By default set to Dynamic Brakes output.
40	Output Location for F6	O	Y	16	By default set to Doppler output.
41	Output Location for F7	O	Y	32	By default set to Air Brakes output.
42	Output Location for F8	O	Y	64	By default set to Mute output.
43	Output Location for F9	O	Y	16	By default set to Heavy Load output.
44	Output Location for F10	O	Y	32	By default set to Status Report output.
45	Output Location for F11	O	Y	64	By default set to Number Boards output.
46	Output Location for F12	O	Y	128	By default set to Cab Lights output.
47	Reserved by NMRA for future use	-	-		
48	Reserved by NMRA for future use	-	-		
49	QSI Primary Index	O	Y	0	"PI" for short.
50	QSI Secondary Index	O	Y	0	"SI" for short.
51	QSI System Sound Control	O	Y		1-dimensional table[PI]
52	QSI Individual Sound Volume Control	O	Y		1-dimensional table[PI]
53	QSI Function Output Feature Assignment	O	Y		2-dimensional table[PI,SI]
54	Reserved by QSI for future use	-	-		
55	QSI Feature Configuration	O	Y		2-dimensional table[PI,SI]
56	QSI Configuration	O	Y		2-dimensional table[PI,SI]
57	Reserved by QSI for future use	-	-		
58	Odometer	-	-		
59	Reserved by QSI for future use	-	-		
60	Reserved by QSI for future use	-	-		
61	Reserved by QSI for future use	-	-		
62	QSI Control	O	Y	1	Turn on/off programming verbal acknowledgement.
63	Reserved by QSI for future use	-	-		
64	Verbal CV Inquiry	O	Y		Decoder speaks out value of any CV.
65	Kick Start	O	N	-	
66	Forward Trim	O	Y	128	
67	Speed Step 1	O	Y	0	
68	Speed Step 2	O	Y	9	
69	Speed Step 3	O	Y	18	
70	Speed Step 4	O	Y	28	
71	Speed Step 5	O	Y	37	
72	Speed Step 6	O	Y	47	
73	Speed Step 7	O	Y	56	
74	Speed Step 8	O	Y	66	
75	Speed Step 9	O	Y	75	
76	Speed Step 10	O	Y	85	
77	Speed Step 11	O	Y	94	
78	Speed Step 12	O	Y	103	
79	Speed Step 13	O	Y	113	
80	Speed Step 14	O	Y	122	
81	Speed Step 15	O	Y	132	
82	Speed Step 16	O	Y	141	
83	Speed Step 17	O	Y	151	
84	Speed Step 18	O	Y	160	
85	Speed Step 19	O	Y	170	
86	Speed Step 20	O	Y	179	
87	Speed Step 21	O	Y	188	

88	Speed Step 22	O	Y	198	
89	Speed Step 23	O	Y	207	
90	Speed Step 24	O	Y	217	
91	Speed Step 25	O	Y	226	
92	Speed Step 26	O	Y	236	
93	Speed Step 27	O	Y	245	
94	Speed Step 28	O	Y	255	
95	Reverse Trim	O	Y	128	
96	Reserved by NMRA for future use	-	-		
97	Reserved by NMRA for future use	-	-		
98	Reserved by NMRA for future use	-	-		
99	Reserved by NMRA for future use	-	-		
100	Reserved by NMRA for future use	-	-		
101	Reserved by NMRA for future use	-	-		
102	Reserved by NMRA for future use	-	-		
103	Reserved by NMRA for future use	-	-		
104	Reserved by NMRA for future use	-	-		
105	User Identifier #1	O	N		
106	User Identifier #2	O	N		
107	Reserved by NMRA for future use	-	-		
:	:	-	-		
512	Reserved by NMRA for future use	-	-		

2.4 Overview of CV Descriptions

The following sections provide detailed descriptions of each CV supported by the Quantum System. Each description includes the default value, a pictorial of the CV data register and sometimes, operational hints or notes about special use and limitations.

The data for each bit shown in the pictorial data registers are classified as:

"**A**" for Address data

"**D**" for general data

"**F**" for Function Designation value

"**Sign**" for plus or minus sign.

"**N/A**" for Not Applicable meaning the user is not to enter data in these bits.

"**Output**" for assigning different Output locations for Function Inputs.

"**P**" for QSI Primary Index values

"**S**" for QSI Secondary Index values

"**V**" for audio volume data

In addition, QSI or NMRA pre-assigned data for individual bits in CV registers are shown as their binary value, "1" or "0".

Examples:

CV 1: Primary Address Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	**A6**	**A5**	**A4**	**A3**	**A2**	**A1**	**A0**

Bits 0-6 are data bits, which specify the locomotive's seven bit Primary Address. A zero means, "Do not attempt to write a 1 to this bit".

CV 49: Primary Index Register

Bit 7 (MSB)	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0 (LSB)
P7	**P6**	**P5**	**P4**	**P3**	**P2**	**P1**	**P0**

Bits 0-7 are data bits, which specify any of the possible eight bit Primary Index values.

CV 40: F6 Output Location for F6 Register (with Factory Default Features)

Heavy Load (Disconnect-Standby-Total Shut Down)	Mute	Squealing Brakes – Air Brakes (Brake Set)	Doppler (Start Up)	Dynamic Brakes	Blower Hiss/Fans	Coupler Crash Coupler Fire (Coupler Arm)	Horn/Whistle
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Output 11	**Output 10**	**Output 9**	**Output 8**	**Output 7**	**Output 6**	**Output 5**	**Output 4**

The "**Output 4**" means that bit 0 specifies whether Output 4 is controlled by Function Key 6.

Gray background for an Output bit means that it is the default setting.

3 CV's 1-29: NMRA Standard CV's

This section describes in detail NMRA standard CV's supported by Quantum locomotives.

3.1 CV 1 Primary Address Control

Programs the Short or Primary Address from 1 to 127 decimal.

Default Value: **3**

CV 1: Primary Address Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	**A6**	**A5**	**A4**	**A3**	**A2**	**A1**	**A0**

- Any attempt to set this CV to any value outside the range of 1 to 127 will be ignored and the previous address in this register will remain.
- The Primary Address can be set either in Service Mode or Operations Mode. Remember to change bit 5 of CV 29 to "0" to enable the Primary Address.

Note: Some Command Stations will not operate Quantum Systems in Service Mode due to insufficient power output or timing problems. (Check the appendices for a listing of recommended command stations). If you cannot operate in Service Mode, use Ops Mode programming.

If your command station will not allow setting ID numbers in Ops Mode, use QSI CV 56.129.

3.2 CV 2 V-Start

V-Start defines the voltage drive level applied to the motor at the first throttle speed step. Use CV 2 to adjust the responsiveness of your locomotive at low throttle settings.

Default Value: **32**

CV 2: V-Start Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- CV 2 sets a start voltage for the motor to any value between 0 and 255. A value of 0 provides no offset while a value of 255 provides maximum starting voltage with no throttle range left.

  CV 2 specifies how much of the available track voltage will be applied to the motor at the start of the throttle range as defined by the following equation:

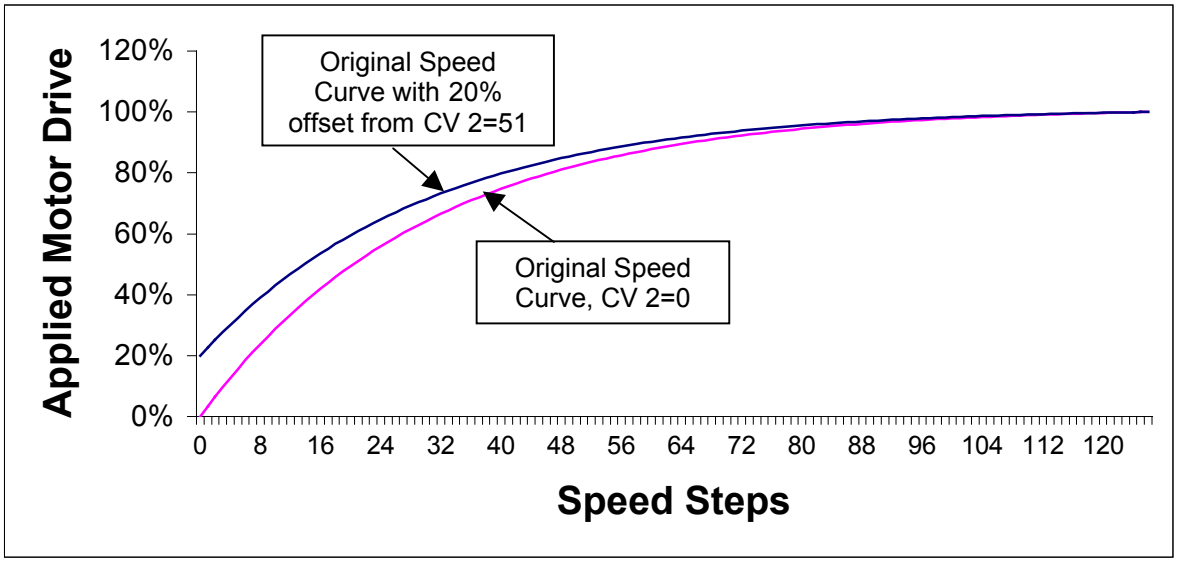
  Start Voltage = (Track Voltage) x (CV2/255)

- The value of motor drive (as a percentage of total track voltage) is computed according to the formula below:

% Applied Motor Voltage = (CV 2 + ((CV5-CV 2)*Speed Table Value for speed step/255))*(100/255)

If CV 5 is less than or equal to CV 2, or CV 5 is set to 0 or 1, then 255 is used for CV 5 in the above equation.

The graph below shows the original curve plus the effect of an offset of 20% (CV 2 = 51 and assuming CV 5, V-High, is set at its maximum value of 255). Note how CV 2 preserves the shape of the original speed curve but compresses it to fit between V-Start and V-High.



- DCC V Start is not related to V Start for Analog Operation.
- V-Start is not used when Throttle Mode = Calibrated Speed Control .
- See CV 5 for more information.

3.3 CV 3 Acceleration Rate[32]

Sets the value of Inertia under Acceleration

Default Value: **0**

CV 3: Acceleration Rate Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- CV 3 can contain any value between 0 and 255. A value of "0" provides no inertia and gives the fastest response to changes in throttle position.

- The larger the value of CV 3, the more gradually the locomotive increases speed as the throttle is increased. The inertia, in seconds/speed step, is calculated by the formula:

$$\textbf{Acceleration Inertia (seconds/speed step)} = \frac{\textbf{(CV 3) * 0.896}}{\textbf{Number of Speed Steps}}$$

  This inertia is independent of which "Number of Speed Steps" is in use (14, 28, or 128). For the same value of CV 3, it will take the same amount of time to go from a dead stop to full speed for a throttle change from minimum to maximum regardless of the speed step choice. The time can vary from a quick response measured in seconds for CV 3=0 to as long as 3.8 minutes (228 seconds) for CV 3 = 255.

- The acceleration rate is the inverse of the inertia formula.

$$\textbf{Acceleration Rate (speed steps/second)} = \frac{\textbf{Number of speed steps}}{\textbf{(CV 3)* 0.896}}$$

- The acceleration and deceleration rate values in CV 3 and CV 4 will apply if you change the direction on a moving locomotive. The locomotive will slow to a stop at a rate set by CV 4 and then accelerate in the opposite direction at a rate set by CV 3.

32 This NMRA CV is more aptly entitled "Inertia under Acceleration" since higher values for this CV result in higher inertia values but lower acceleration rates. Using the term "Momentum" to describe CV 3 is not correct since a non-moving train has no momentum even if CV 3 is set to the maximum value. Inertia is the property of an object that resists any change to its state of rest or motion.

3.4 CV 4 Deceleration Rate[33]

Sets the Inertia under Deceleration.

Default Value: **0**

CV 4: Deceleration Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- CV 4 can contain any value between 0 and 255. A value of "0" provides no inertia and gives the fastest response to changes in throttle position.
- The larger the value of CV 4, the more gradually the locomotive slows down as the throttle is decreased. The inertia, in seconds/speed step, is calculated by the formula:.

  Deceleration Inertia (seconds/speed step) = $\frac{\text{(CV 4) * 0.896}}{\text{Number of Speed Steps}}$

  This inertia is independent of which "Number of Speed Steps" is in use (14, 28, or 128). For the same value of CV 4, it will take the same amount of time to go from full speed to a dead stop for a throttle change from maximum to minimum regardless of the speed step choice. The time can vary from a quick response measured in seconds for CV 4=0 to as long as 3.8 minutes (228 seconds) for CV 4 = 255.
- The deceleration rate is the inverse of the above formula.

  Deceleration Rate (speed steps/second) = $\frac{\text{Number of speed steps}}{\text{(CV 4)* 0.896}}$
- The acceleration and deceleration rate values in CV 3 and CV 4 will apply if you change the direction of a moving locomotive. The locomotive will slow to a stop at a rate set by CV 4 and then accelerate in the opposite direction at a rate set by CV 3.

33 This NMRA name is more aptly entitled "Inertia under Deceleration" since higher values for this CV result in higher inertia values but lower deceleration rates. Using the term "Momentum" to describe CV 3 is not correct since a non-moving train has no momentum even if CV 3 is set to the maximum value. Inertia is the property of an object that resists any change to its state of rest or motion.

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3.5 CV 5 V-High

V-High defines the voltage drive level applied to the motor at maximum throttle. Use CV 5 to reduce the maximum speed of locomotives that operate too fast at maximum throttle.

Default Value: **1**

CV 5: V-High Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- CV 5 sets a maximum voltage for the motor to any value between 2 and 255. A value of 0, 1, or 255 provides maximum motor voltage at maximum throttle.

  The value of CV 5 determines the maximum motor drive as a fraction of the applied voltage as defined by the following equation:

  Maximum Motor Voltage = (Track Voltage) x (CV5/255)

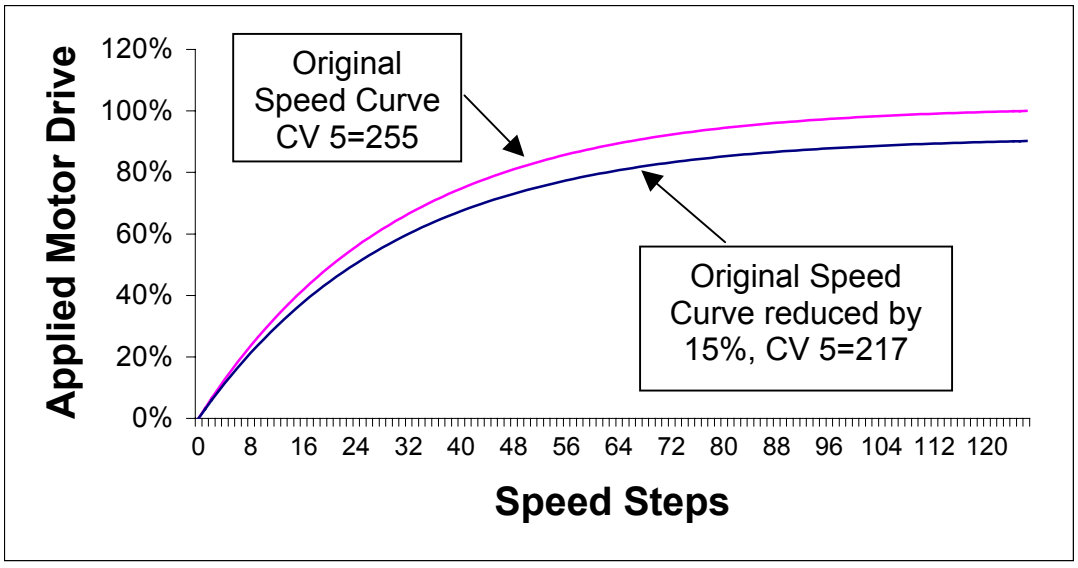
  For instance, a value of "200" for CV 5 means that the maximum voltage will be 217/255 or 85% of the applied track voltage.

- The value of motor drive (as a percentage of total track voltage) is computed according to the formula below:

% Applied Motor Voltage = (CV 2 + ((CV5-CV 2)*Speed Table Value for speed step/255))*(100/255)

If CV 5 is less than or equal to CV 2, or CV 5 is set to 0 or 1, then 255 is used for CV 5 in the above equations.

The graph below shows the effect of only CV 5 (CV 2 =0) on the original curve. Here a value of CV 5 = 217 reduces the original speed curve by 15% over the entire speed step range. Note how CV 5 preserves the shape of the original speed curve but compresses it to fit between V-Start and V-High.

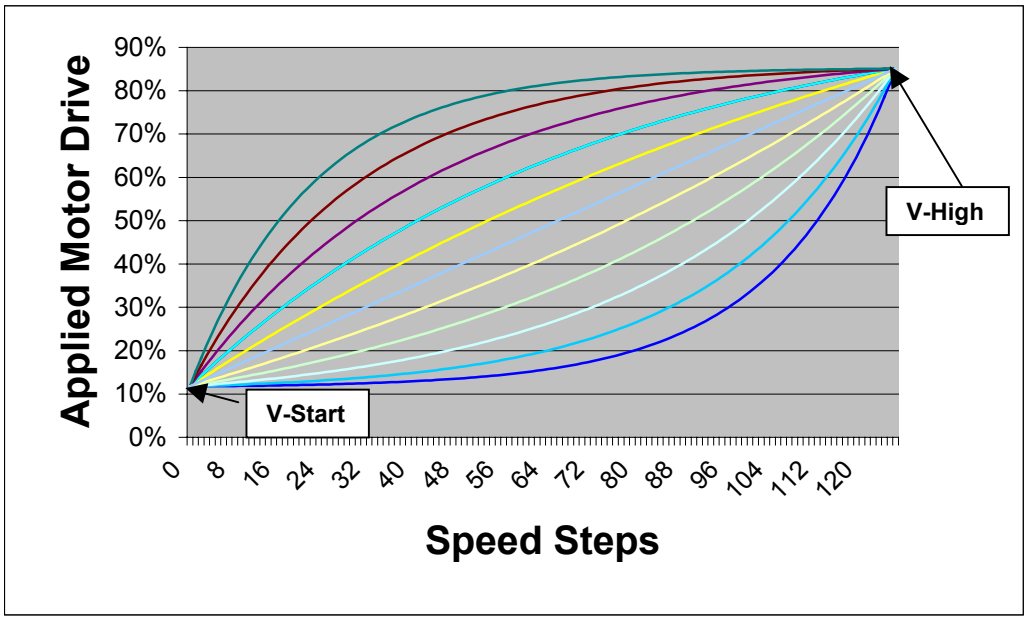


V-High is not related to V Max for Analog Operation.
V-High is not used when Throttle Mode = Calibrated Speed Control.

Recommendations for specifying speed curves, V-Start and V-High.

The following is a method we use at QSI to configure a locomotive to match the speed of other locomotives. We use Ops mode programming since it lets us change the locomotive's speed characteristics while the locomotive is operating.

1. Place your locomotive to be configured (call it locomotive A) on a fairly large loop of track. Place your standard locomotive[34] (call it locomotive B) that you use as your speed reference on the same loop of track but on the opposite side. Each locomotive should have a different ID.
2. For both locomotives set CV 56.4 to "0" (STC) or "1" (RTC).
3. For both locomotives set CV 29 bit 4 to "1" to enable speed curves.
4. Run both locomotives at speed step 1.
5. Change locomotive A's CV 2 value until it is moving at the same speed as locomotive B.
6. Run both locomotives at full throttle. You may have to restrain one of the locomotives if they get too close to each other.
7. Change locomotive A's CV 5 value until Locomotive A is moving at the same speed as Locomotive B.
8. Set both locomotives to speed step 64. For locomotive A, choose speed curves from the list of QSI speed curves from CV 25 until both locomotives are running at a similar speed. The speed curves are compressed to fit between V-High and V-Start as shown in the graph below.



Speed Curves with V-Start set to 30 (10% of applied voltage) and V-High set to 217 (85% of applied voltage).

9. If none of the speed curves are acceptable, set CV 25 to 1 and make your own custom speed curve using CV 67 through CV 94. Your custom speed curve will also be compressed to fit within the limits set by V-Start and V-High. Set both locomotives at 28 speed-step selection so your custom changes are at the speed step the locomotive is operating at. Start both locomotives at speed step 1; enter Ops mode programming for Locomotive A and set CV 67 to match Locomotive B speed. Leave Ops mode programming, and set both locomotives to operate at speed step 2, enter Ops mode programming for Locomotive B and set CV 68 to match Locomotive B speed. Repeat this procedure until you have entered speed curve values for all CV's between CV 67 and CV 94.

34 You may have a number of standard locomotives for different speed classifications. For instance, you might have a standard locomotive for yard operations with a top speed of 35 smph, a standard freight locomotive with a top speed of 65 smph and a third standard locomotive for passenger service with a top speed of 100 smph.

3.6 CV 7 Manufacturer's Version Number

This is a read only CV that returns the major version number of the decoder's firmware.

Default Value: **N/A**

CV 7: Manufacturer's Version Number Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- Production release versions start with 1. If your locomotive has a 1 in this register, your locomotive contains the first version of Quantum HO firmware. A "2" in this register corresponds to the second version of Quantum HO firmware.

- This DCC Reference Manual describes CV's supported by version 7 firmware. If your Quantum locomotive has a value of 1…6 in this CV, version 3.1 of the DCC Reference Manual more accurately describes your locomotive's firmware.

3.7 CV 8 Manufacturer's ID

This read-only CV identifies QSI as the manufacturer or developer of the software used in the Quantum System.

Default Value: **113**

CV 8: Manufacturer's ID Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	**1**	**1**	**1**	**0**	**0**	**0**	**1**

- The value of this read only register is 113, which is the official NMRA designation for QSI as a manufacturer of DCC decoders.

3.8 CV 11 Packet Time-Out Value

The value in CV 11 is the maximum time the decoder will maintain its current speed without receiving a valid DCC packet.

Default Value: **1**

CV 11: Packet Time-Out Value Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
N/A	**N/A**	**N/A**	**D4**	**D3**	**D2**	**D1**	**D0**

- If CV 11 has a non-zero value, and the locomotive receives no DCC packets addressed to the locomotive for that number of seconds then the locomotive will decelerate to a stop at a rate specified by CV 4 and CV 24 and will enter Neutral. The usual Neutral Sounds will then be heard.
- When DCC packets addressed to the locomotive are again received, the locomotive will respond to the DCC packet commands addressed to the locomotive. It will remain in Neutral until a new speed packet is received at which time it will accelerate at the rate set in CV 3 and CV 23.
- A value of zero will disable the time-out function and the locomotive will continue to run at its last speed setting when it stops receiving packets addressed to the locomotive.
- The factory default is “1” which is interpreted as 1 second.
- The maximum value for CV 11 is 20, interpreted as 20 seconds[35]. If any value greater than 20 is written to this CV, the new value is ignored and CV 11 retains its previous value.
- If both Power Source Conversion (CV 29, bit 2) and Packet time-out Value are enabled, Power Source Conversion takes precedence, since it will always have the shorter time-out period.

35 Twenty seconds is the maximum time specified in NMRA Recommended Practice RP-9.2.4.

3.9 CV 17, 18 Extended Address

CV 17 and CV 18 together provide a larger (14 bit) range for locomotive ID numbers from 0 to 10,239.

CV 17 Default Value:	0[36]
CV 18 Default Value	0

CV 17: Extended Address Most Significant Byte Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
1	**1**	**A13**	**A12**	**A11**	**A10**	**A9**	**A8**

CV 18: Extended Address Least Significant Byte Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
A7	**A6**	**A5**	**A4**	**A3**	**A2**	**A1**	**A0**

- Use CV 17 and CV 18 to assign your locomotive one of 10,240 addresses from 0 to 10,239, although most Command Stations will only allow entering ID's up to 9,999. You can assign your locomotive an address that is identical to the locomotive's cab number, which rarely exceed four digits.
- Your locomotive can have both a Primary Address (CV 1) and an Extended Address. There is overlap in the Primary Address and Extended Address range 1…127 so that a locomotive can have the same number for its Primary Address as it has for its Extended Address. For example, a locomotive can have Primary Address "53" and Extended Address "53". Although the same number, these two addresses are not the same and are treated differently by your locomotive and your Command Station. See your Command Station Instructions to learn how to tell the difference between the two addresses.
- The Extended Address can be set either in Service Mode or Operations Mode. Remember to change bit 5 of Configuration CV 29 to "1" to enable the Extended Address.

3.9.1 Entering Extended Address into CV 17 and CV 18 Directly:

Most modern Command Stations allow the operator to input an Extended Address from 0 to 9999 directly in decimal format without having to individually enter data into CV 17 and CV 18. However, if you have an older Command Station and need to program these CV's directly, the following information will be helpful.

- ♦ CV 17 and CV 18 form a paired CV and it makes a difference how data is entered. CV 17, the most significant byte, must be written first followed by CV 18, the least significant byte. If the order is reversed, the Quantum decoder will not accept the values entered.
- ♦ Bits A15 and A14 must both be assigned "1" which adds 192 to the value of the byte in CV 17. The remaining 6 bits of C17 and the 8 bits of C18 allow addresses to be assigned between 0 and 10,239 inclusive. Any attempt to program an extended ID above 10,239 will be ignored.

To enter CV 17 and CV 18 by direct programming, first divide the decimal address you intend to enter by 256, convert the quotient to binary, add the two leading 1's for bits A14 and A15, and write the result to CV 17. Convert the remainder to binary and write this number to CV 18.

36 The default for CV 17 is actually "192" which is an artifact of how these ID numbers are specified by the NRMA where 192 is added to the MSB (Most Significant Byte) of the address you want to enter. If you have a modern Command Station that programs your ID numbers directly, you will enter your ID number equal to the Extended Address you intend to use; however, if you program the extended address CV directly, a zero address must be entered as 192. See example in this section on directly programming CV 17 and CV 18.

Example1 Decimal Entry: Program CV 17 and CV 18 to Extended Address 5343.

Divide 5343 by 256 to get 20 as quotient and 223 as remainder.

Note: If you use a calculator, you will get 20.8711. Note the integer value n = 20, which is the quotient.

Add 192 to this quotient to get 212 and store this value in CV 17:

CV 17 = n + 192

CV 17 = 20 + 192 = 212

Compute the remaining integer value by multiplying 20 by 256 and subtract from the locomotive value to get remainder and store in CV 18:

CV 18 = Locomotive Number – (n X 256)

CV 18 = 5343 – (20 X 256) = 223

Remember to change CV 29, bit 5 to "1" to allow the Extended Address operation (see CV 29).

Example2 Binary or Hex Entry: Program CV 17 and CV 18 to Extended Address 5343.

Convert 212 from previous example to binary 11010100 or hex 0xD4. Enter this number in CV 17.

Convert 223 from previous example to binary 11011111 or hex 0xDF and enter in CV 18.

Remember to change CV 29, bit 5 to "1" to allow the Extended Address operation (see CV 29).

To check: Compute (CV 17 – 192)*(256) + CV 18 where 192 is the decimal equivalent of CV 17 with only the leading 1's (11000000)

Decimal: (212 – 192)*(256) + 223 = **5343**

Binary: (11010100 –11000000)*(100000000) + 11011111 = 1010011011111 = **5343** decimal.

Hex: (0xD4– 0xC0)*0x100 + 0xDF = 0x14DF = **5343** decimal, where 0xC0 is the hex equivalent of 192.

The following table shows examples for some common Steam locomotive cab numbers. See if your calculations match the values in the table. After you have calculated your ID numbers, just follow the procedure below to enter your extended ID number.

1. Find out if your command station accepts Decimal, Binary or Hex inputs for CV entries.
2. First enter CV 17 (Most Significant Byte) from the table below as a Decimal, Binary or Hex number shown.
3. Next enter CV 18 (Least Significant Byte) from the table below as a Decimal, Binary or Hex number shown.
4. Change CV 29, bit 5 to "1" to allow operation with your new Extended Address.
5. Read your ID number back from your program track or verbally in Opts Mode to see if you entered the correct number.

Common Steam Locomotive Numbers

Loco Number	CV 17 (Dec)	CV 18 (Dec)	CV 17 (Hex)	CV 18 (Hex)	CV 17 (Binary)	CV 18 (Binary)
3985	207	145	CF	91	11001111	10010001
611	194	99	C2	63	11000010	01100011
8444	224	252	E0	FC	11100000	11111100
4449	209	97	D1	61	11010001	01100001
3751	206	167	CE	A7	11001110	10100111
261	193	5	C1	5	11000001	00000101
1218	196	194	C4	C2	11000100	11000010
1361	197	81	C5	51	11000101	01010001
700	194	188	C2	BC	11000010	10111100

Note: Some command stations will not operate Quantum Systems in Service Mode due to insufficient power output or timing problems. (Check the appendices for a listing of recommended command stations). If you cannot operate in Service Mode, use Ops mode programming.

If your command station will not allow setting ID numbers in Ops Mode, use QSI CV 56.129 to enter your ID numbers.

3.10 CV 19 Consist Address

Sets a locomotive's Consist[37] address in addition to setting the locomotive's direction within the Consist.

Default Value: **0**

CV 19: Consist Address Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**A6**	**A5**	**A4**	**A3**	**A2**	**A1**	**A0**

- Bits A0-A6 set the Consist address to any value from 0 to 127.
- Bit D7 sets the locomotive's direction. "0" in D7 sets the locomotive to a normal Forward and "1" sets locomotive to Reverse Direction within the Consist.
- If the address in bits 0-6 is 0, the locomotive is not in a Consist.
- If the seven bit address has a value 1…127, when decoder receives a command packet addressed to this address, the packet will be processed as any other packet except,
  - The direction bit in a speed/direction or advanced operation packet is inverted if D7=1.
  - Function Key commands are ignored unless enabled in CV's 21 and 22.
  - Long Form CV Access instructions will be ignored.
  - Only Short Form CV Access instructions for CV's 23 and 24 are allowed.
- If a locomotive has the same Consist Address as its Primary Address, it will respond to commands as through it were being addressed by its Primary Address without the restrictions set in CV 21 and CV 22.

37 Consists are also know as Multiple Heading, Lashups or Multiple Unit Trains (MU's) .

3.11 CV 21 Consist Address Active for F1-F8[38]

Sets which Function Keys are enabled when a locomotive is addressed by its Consist ID.

Default Value: **0**

CV 21: Consist Address Active for F1-F8 Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
F8	**F7**	**F6**	**F5**	**F4**	**F3**	**F2**	**F1**

- If a “0” is placed in any bit, that function key is disabled when the locomotive is addressed by its Consist ID.
- If a “1” is placed in any bit, that function key is enabled when the locomotive is addressed by its Consist ID.
- This CV is useful for disabling certain features for helper locomotives within the Consist. For instance, only the Lead locomotive should have its Horn/ Whistle and Bell enabled. If the F2 key controls the Horn and the F3 key controls the Bell, then all slave locomotives should have "0" in Bit 1 and Bit 2, while the Lead locomotive should have “1” in these bits.
- The following recommended values are for locomotives that have factory default features assigned to Function Outputs (see CV 53) . Features that are different in the Neutral State are shown with parentheses (i.e. Doppler (Start Up) means Doppler is only operable in Forward and Reverse and Start Up is operable only in Neutral). Features shown that do not indicate a special Neutral Option, will operate in all states (Forward, Neutral and Reverse).

Recommended value of CV 21 for a Lead Locomotive in a Consist.

(The QSI default features assignments are shown for Forward/Reverse operation in the top row and for Neutral in parenthesis).

Audio Mute	Brake Squeal and Air Brakes (Arm Cylinder Cocks or long Air Let-Off)	Doppler (Start Up)	Dynamic Brakes	Blower Hiss/Fans	Coupler Crash Coupler Fire (Coupler Arm)	Horn/Whistle	Bell
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
1	**1**	**1**	**1**	**1**	**0**	**1**	**1**

Recommended value of CV 21 for a Mid[39] Helper Locomotive in a Consist.

(The QSI default features assignments are shown for Forward/Reverse operation in the top row and for Neutral in parenthesis).

Audio Mute	Brake Squeal and Air Brakes (Arm Cylinder Cocks or long Air Let-Off)	Doppler (Start Up)	Dynamic Brakes	Blower Hiss/Fans	Coupler Crash	Horn/Whistle	Bell
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
1	**1**	**1**	**1**	**1**	**0**	**0**	**0**

38 Write bit operation is supported for CV 21.
39 A Mid Helper is any locomotive between the Lead and the last or End helper in a Consist.

Recommended value of CV 21 for an End[40] Helper Locomotive in a Consist.
(The QSI default features assignments are shown for Forward/Reverse operation in the top row and for Neutral in parenthesis).

Audio Mute	Brake Squeal and Air Brakes (Arm Cylinder Cocks or long Air Let-Off)	Doppler (Start Up)	Dynamic Brakes	Blower Hiss/Fans	Coupler Crash	Horn/Whistle	Bell
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
1	**1**	**1**	**1**	**1**	**1**	**0**	**0**

3.12 CV 22 Consist Address Active for FL and F9-F12[41]

Sets whether the FL(r) or FL(f) keys and F9-F12 keys are enabled when a locomotive is addressed by its Consist ID.

Default Value: **0**

CV 22: Consist Address Active for FL and F9-F12 Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	**0**	**F12**	**F11**	**F10**	**F9**	**FL(r)**	**FL(f)**

- If a “0” is placed in bits 0 through 5, that function key is disabled when the locomotive is addressed by its Consist ID.
- If a “1” is placed in bits 0 through 5, that function key is enabled when the locomotive is addressed by its Consist ID.
- Any "1" placed in bits 6 or 7 will be ignored.
- FL in the Forward Direction is controlled by bit 0, FL in the Reverse Direction is controlled by bit 1.
- This CV and CV 21 are useful for disabling certain features for Helper locomotives within the Consist.
    - ♦ Only the Lead Locomotive should have operational Directional Lighting. Helpers should have their Directional Lighting disabled.
    - ♦ F9, Heavy Load and Shut Down are recommended for all Helper types in a Consist since Heavy Load should apply to all locomotives or none at all; otherwise there would be fighting between locomotives that have Heavy Load enabled and those that do not. Similarly, the F9 Shut Down key should apply to all locomotives in Consist or none at all.
    - ♦ F10, Status Report should be disabled for all Helper types in a Consist since it would be difficult to hear the verbal announcement if more than one locomotive announced its status at the same time.
    - ♦ Features for Function keys 11 and 12 are usually reserved for Number Board Lights and Cab Lights. It is recommended that Cab Lights be disabled and Number Board Lights be enabled. At times F11 and F12 are reserved for custom appliance sounds or operations for the different locomotive types (Steam, Diesel or Electric) such as steam Blow Down, etc. It is recommended that these functions be disabled for all Helper types except the Lead Locomotive to avoid confusion. Check your individual models to determine which features are assigned to F11 and F12.

40 An End Helper is the last helper in a consist.
41 Write bit operation is supported for CV 22.

- The following recommended values are for locomotives that have factory default values assigned to FL Outputs (see CV 53). Features that are different in the Neutral State are shown with parentheses; i.e. Heavy Load (Shut Down) means Heavy Load is only operable in Forward and Reverse and Shut Down is operable only in Neutral.

Recommended value of CV 22 for a Lead Locomotive in a Consist:

N/A	N/A	Cab Lights	Number Board Lights	SMPH Report (Status Report)	Heavy Load (Disconnect-Standby-Total Shut Down)	Directional Lighting	Directional Lighting
N/A	N/A	F12	F11	F10	F9	FL(r)	FL(f)
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	**0**	**0**	**1**	**1**	**1**	**1**	**1**

Recommended value of CV 22 for a Mid Helper Locomotive in a Consist:

N/A	N/A	Cab Lights	Number Board Lights	SMPH Report (Status Report)	Heavy Load (Disconnect-Standby-Total Shut Down)	Directional Lighting	Directional Lighting
N/A	N/A	F12	F11	F10	F9	FL(r)	FL(f)
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	**0**	**0**	**1**	**0**	**1**	**0**	**0**

Recommended value of CV 22 for an End Helper Locomotive in a Consist:

N/A	N/A	Cab Lights	Number Board Lights	SMPH Report (Status Report)	Heavy Load (Disconnect-Standby-Total Shut Down)	Directional Lighting	Directional Lighting
N/A	N/A	F12	F11	F10	F9	FL(r)	FL(f)
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	**0**	**0**	**1**	**0**	**1**	**0**	**0**

When making up your consist, remember to have the directional lighting turned off before you assign zeros for bits 0 and 1. Otherwise the directional lighting will be on with no way to turn them off with the FL(r) or FL(f) keys[42].

The above selections for directional lighting for locomotives in a consist are not ideal for the following reasons:

1. You may not want the Lead Locomotive to have an operating Directional Reverse Light since it would only illuminate the locomotive behind it and not the track. The simplest way to have the reverse light off in all motive states is to set CV55.73.1 to 0.
2. You may want the End Helper to have an operational reverse facing light (which may be either the End Helper's Reverse Light or Headlight depending on the locomotive's direction within the consist). If the End Helper is facing Forward, set CV55.70.1 to 0, CV55.73.1 to 32, and set bit 0 and bit 1 in CV 22 to 1. If the End Helper is facing Backwards, set CV55.70.1 to 86, CV55.73.1 to 0, and set bit 0 and bit 1 in CV 22 to 1.

With the above changes, the directional lighting in your consist will operate like a single locomotive. That is, the FL key is on, the Lead Locomotive Directional Headlight will be on, all other Helper Headlights will be off, and all Reverse Lights will be off. If the consist is moving in Reverse, only the End Helper Reverse Light will be on and the Lead Locomotive Headlight will either be off or Dim (if the Dim feature is part of the Directional Headlight for your model).

42 Since the default for directional lighting is off, any helpers that did have their directional lighting on will be set to off if the power is turned off and back on, or if the locomotive is shut down and started using the F9 and F6 keys.

3.13 CV 23 Acceleration Adjustment

Increases or decreases the Acceleration from the base Acceleration Rate in CV 3.

Default Value: **0**

CV 23: Acceleration Adjustment Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Sign	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- CV 23 can have any value from –127 to +127 where positive values will increase the acceleration time and negative values will decrease the acceleration time. A positive value is indicated by a 0 in bit 7 while a "1" indicates a negative value.
- A positive value of CV 23 adds directly to the value of CV 3 by the formula below:

$$\textbf{Seconds/speed step} = \frac{\textbf{(CV 3 + CV 23) * 0.896}}{\textbf{Number of Speed Steps}}$$

- The purpose of CV 23 is to allow the operator to simulate differing train lengths/loads, most often when operating in Consists. It can, however, apply to single locomotives as well.

3.14 CV 24 Deceleration Adjustment

Increases or decreases the Deceleration from the base Deceleration Rate in CV 4.

Default Value: **0**

CV 24: Deceleration Adjustment Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Sign	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- CV 24 can have any value from –127 to +127 where positive values will increase the deceleration time and negative values will decrease the deceleration time. A positive value is indicated by a 0 in bit 7 while a "1" indicates a negative value.
- A positive value of CV 24 adds directly to the value of CV 4 by the formula below:

$$\textbf{Seconds/speed step} = \frac{\textbf{(CV 4 + CV 24) * 0.896}}{\textbf{Number of Speed Steps}}$$

- The purpose of CV 24 is to allow the operator to simulate differing train lengths/loads, most often when operating in Consists. It can, however, apply to single locomotives as well.

3.15 CV 25 Quantum Speed Table Selection

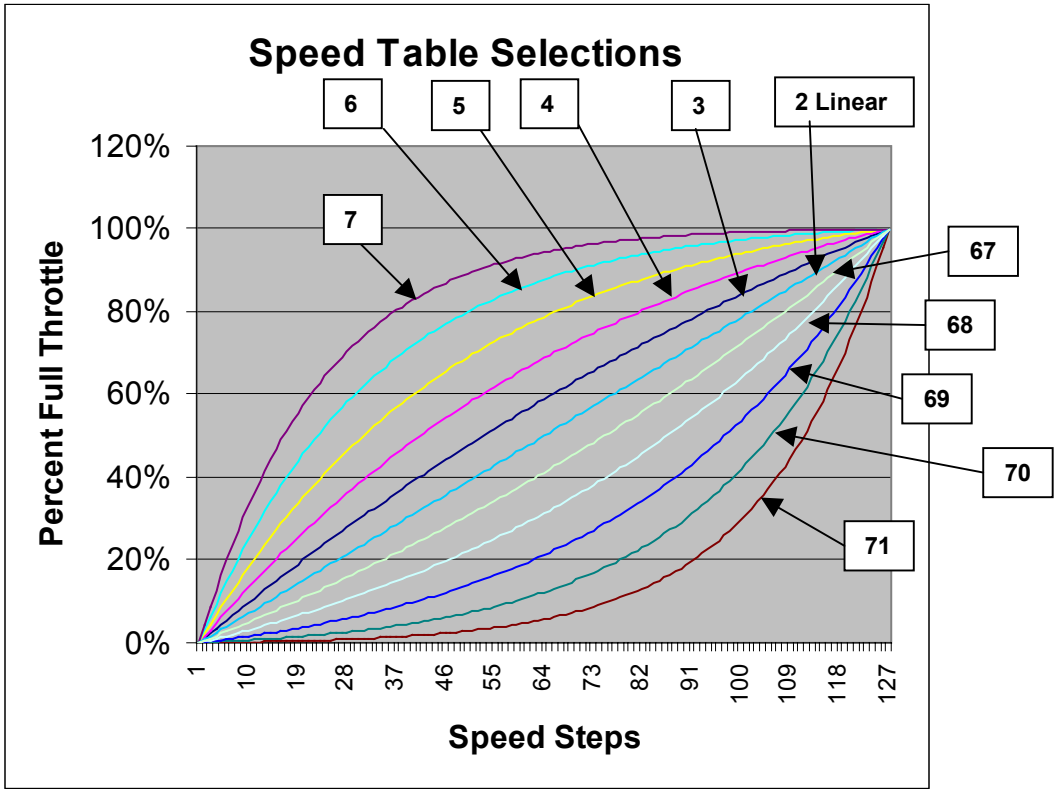
Use this CV to select of one of 11 predefined speed curves..

Default Value: **2**

CV 25: Quantum Speed Table Selection Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	**D6**	**N/A**	**N/A**	**N/A**	**D2**	**D1**	**D0**

- You can select from 11 predefined speed curves that are shown in the graph below. The upper five convex curves are “fast start” curves while the lower five concave curves are “slow start” curves. The “fast start” curves will compensate for locomotives that are less responsive getting started while the “slow start” curves compensate for locomotives that tend to “rocket out” when the throttle is barely turned on.



- To select a predefined speed curve, set CV 25 to the value associated with the curve in the graph above. Set CV 25 to “0” or “1” to select a User Defined Curve (see CV 67 – 94). Set CV 25 to any other number to select a predefined Linear Curve.
- Bit 4 of CV 29 must be set to “1” to enable any of the above speed curves. If CV 29 bit 4 is set to “0”, then a linear straight-line response is enabled.

Additional Information for the Curious Regarding QSI Speed Curves:

- The assignment of bits to this register follows a logical sequence:

Bits 0-2: Determines how much curvature. For low values the curves are closer to linear while higher values provide greater curvature. Bits 0-2 set to 000 or 001 indicates that speed table is not used regardless of the setting in bit 6. Bits 0-2 set to 010 indicate a linear speed table.

Bit 3-5: Reserved for future QSI expansion of speed curves. Any non-zero value entered for these bits will automatically result in a Linear Response regardless of what is entered in other bits.

Bit 6: Determines if it is convex "Fast Start" or concave "Slow Start" curve.
0 = "Fast Start" Convex Curve
1 = "Slow Start" Concave Curve

Bit 7: This bit specifies the mid-range Speed Step and is not supported by Quantum decoders. Set the value to 0. Either a "1" or a "0" is ignored.

The decimal value for each curve from the table below is shown on the above speed graph.

- Curve Tables in order of value for CV 25

Value of CV 25 (Decimal)	Value of CV 25 Bits 7-0 (Binary)	Resulting Speed Table
Convex "Fast Start" Curves		
0	0 0 0 0 0 0 0 0	Reverts to User Defined Speed Table (CV 67-94)
1	0 0 0 0 0 0 0 1	Reverts to User Defined Speed Table (CV 67-94)
2	0 0 0 0 0 0 1 0	Linear Curve
3	0 0 0 0 0 0 1 1	Fast Start 1 (close to linear)
4	0 0 0 0 0 1 0 0	Fast Start 2
5	0 0 0 0 0 1 0 1	Fast Start 3
6	0 0 0 0 0 1 1 0	Fast Start 4
7	0 0 0 0 0 1 1 1	Fast Start 5 (greatest curvature)
Concave "Slow Start" Curves		
64	0 1 0 0 0 0 0 0	Reverts to Linear Curve
65	0 1 0 0 0 0 0 1	Reverts to Linear Curve
66	0 1 0 0 0 0 1 0	Linear Curve
67	0 1 0 0 0 0 1 1	Slow Start 1 (close to linear)
68	0 1 0 0 0 1 0 0	Slow Start 2
69	0 1 0 0 0 1 0 1	Slow Start 3
70	0 1 0 0 0 1 1 0	Slow Start 4
71	0 1 0 0 0 1 1 1	Slow Start 5 (greatest curvature)

- If any of the "Reverts to User Defined Table" values are set in CV 25, then the user specified speed table programmed into CV's 67-94 will be enabled.
- V-Start and V-High settings will apply to these and all curve tables as described in the sections for CV 2 and CV 5. When selecting a speed table, it is recommended that you first select your V-Start offset based on a linear curve and enter this value into CV 2, particularly for concave "slow start" curves where the V-Start point may not be obvious. Setting V-Start for a linear curve will be much more discernible; then select the type of curve you want.

3.16 CV 29 Configuration Data[43]

Each bit in CV 29 controls some basic operational settings for DCC decoders.

Default Value: **00000110 = 6**

CV 29: Configuration Data Register (with NMRA Assigned Features)

Accessory Decoder	Reserved for Future Use	Extended Addressing	Speed Table Enable	Advanced Decoder Acknowledgement	Power Source Conversion	FL Location	Locomotive Direction
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	**N/A**	**D5**	**D4**	**N/A**	**D3**	**D2**	**D1**

- Bit 0 = Locomotive Direction:

  "0" = normal Forward Direction
  "1" = Reversed Direction.

  This bit controls the locomotive's Forward and Reverse direction. With Bit 0 set to 1, the locomotive will move in the Reverse Direction even though the Command Station indicates a Forward Direction. Directional sensitive functions, such as FL(f) and FL(r) , will also be reversed to be consistent with the locomotive's Reversed Direction.

- Bit 1 = Speed Steps and FL Location

  "0" = Bit 4 sets 14 Speed Step Mode.
  "1" = Bit 4 sets 28 and 128 Speed Step Mode.

  In 14 Speed Step Operation, the speed and direction instruction is in one byte of transmitted data that tells the locomotive what direction to go, what speed to travel and whether FL should be "0" or "1". For 28-speed step operation, the bit used for FLis instead used to double the number of speed steps, so that the light state must be transmitted in a Function Group 1 instruction. Similarly, when using 128 speed step mode, bit 1 of CV 29 must be set to "1".

- Bit 2 = Power Source Conversion.

  "0" = Power Source Conversion disabled
  "1" = Power Source Conversion enabled.

  If CV 29 bit 2 is "1", and a period of approximately 200mSec[44] elapses in which no DCC packet is detected, then the locomotive will convert to Analog power.

  If the polarity of the track would result in the locomotive moving in the same direction that it was last moving in DCC mode, then the locomotive will continue to move at the speed corresponding to the last received speed step packet. The usual FWD/REV locomotive sound will be heard.

  If the polarity of the track would result in the locomotive moving the opposite direction than it was last moving in DCC mode, then the locomotive will decelerate to a stop at a rate determined by CV 4 and CV 24, and will enter Neutral. The usual Neutral sounds will be heard.

  When in Analog mode, switching the polarity of the track will either start the locomotive moving or bring it to a stop.

43 Write bit operation is supported for CV 29.

44 NMRA Spec RP-9.2.4 specifies that Power Source Conversion should take place when DCC packets are absent for more than 30 mSec. However Quantum requires approximately 200mSec to determine the Analog track polarity.

If the locomotive is moving and the polarity is reversed, the locomotive will decelerate to a stop at a rate determined by CV 4 and CV 24 and will enter Neutral.

If the locomotive is stopped in Neutral and the polarity is reversed, the locomotive will accelerate at a rate determined by CV 3 and CV 23 to a speed corresponding to the last received speed step packet.

The actual locomotive speed under Analog power may differ from its speed under DCC power depending on the Analog track voltage and whether the locomotive is using Calibrated Speed Control, Regulated Throttle Control, or Standard Throttle Control (e.g. the locomotive may jerk upon switching to analog power).

NOTE: This bit must be set to 1 in order for the locomotive to operate on an Analog track. See trouble shooting section.

- Bit 3 = Advanced Decoder Acknowledgement (not used)

- Bit 4 = Speed Table set by configuration variables.

  "0" Speed Table not used.
  "1" Speed Table set by CV 25, Quantum Speed Table selection.

  When bit 4 of CV 29 is set to "0" a linear Speed Table is used by default.

- Bit 5 = Extended Address Mode enable

  "0" = The decoder responds to one byte Primary Address (see CV 1).
  "1" = The decoder responds to a two byte Extended Address (see CV 17 and CV 18)

- Bit 6 = Reserved for NMRA future use.

- Bit 7 = Accessory Decoder

  "0" = Multifunction locomotive decoder.
  "1" = Accessory Decoder. .

  Quantum decoders are Multifunction Decoders; this bit cannot be changed.

Some command stations make it easy for you to change CV 29 one bit one at a time. Other command stations require you to enter the value of CV 29 as a complete 8-bit byte. The table below shows all the possible combinations of the five programmable bits supported by Quantum locomotives. Where an "X" appears the feature is enabled and the corresponding CV 29 bit is a "1". The Binary, Decimal, and Hex values are shown for each combination. Choose the features you want enabled and enter the corresponding number into CV 29 using the format recommended by your command station. The default for Quantum decoders is shown in bold type.

CV 29 Common Settings

Extended Addressing	Speed Tables	Power Conversion	28/ 128 speed step	Reversed Direction	Decimal Value	Binary Value	Hex Value
					0	00000000	0x0
				X	1	00000001	0x1
			X		2	00000010	0x2
			X	X	3	00000011	0x3
		X			4	00000100	0x4
		X		X	5	00000101	0x5
		X	**X**		**6**	**00000110**	**0x6**
		X	X	X	7	00000111	0x7
	X				16	00010000	0x10
	X			X	17	00010001	0x11
	X		X		18	00010010	0x12
	X		X	X	19	00010011	0x13
	X	X			20	00010100	0x14
	X	X		X	21	00010101	0x15
	X	X	X		22	00010110	0x16
	X	X	X	X	23	00010111	0x17
X					32	00100000	0x20
X				X	33	00100001	0x21
X			X		34	00100010	0x22
X			X	X	35	00100011	0x23
X		X			36	00100100	0x24
X		X		X	37	00100101	0x25
X		X	X		38	00100110	0x26
X		X	X	X	39	00100111	0x27
X	X				48	00110000	0x30
X	X			X	49	00110001	0x31
X	X		X		50	00110010	0x32
X	X		X	X	51	00110011	0x33
X	X	X			52	00110100	0x34
X	X	X		X	53	00110101	0x35
X	X	X	X		54	00110110	0x36
X	X	X	X	X	55	00110111	0x37

4 CV's 33-46: Output Locations[45]

4.1 Overview

The NMRA standard currently provides for fourteen Function Inputs, which are transmitted to the locomotive decoder to control different Outputs. These fourteen Function Inputs are generally operated by thirteen[46] Function Keys (FL, F1, F2, F3, F4, F5, F6, F7, F8, F9, F10, F11 and F12) on the command station or the hand held throttle. The FL[47] Function Key can produce two different Function Inputs, called FL(r) and FL(f), depending on the direction of the locomotive.

The NMRA standard provides for fourteen Outputs, numbered from 1 to 14. CV's 33 through 46 specify which Function Input is connected to which Output.

Note: Q2 firmware built after 1-June-08 does not support CV's 33-46. The following fixed mapping is used:

FL(f) -> Output 1
FL(r) -> Output 2
F1 -> Output 3
…
F12 -> Output 14

The table below shows Output numbers across the top and Function Inputs along the side. The CV number associated with each Function Input is shown in the first column. Each of these CV's consists of an eight bit register with a "1" or "0" in each bit location, specifying which Outputs are controlled by that Function Input. The default value for each CV is shown.

CV #	Function Inputs	Output Numbers and Pre-assigned Features													
	Common Default Quantum Feature Assignments	Cab Lights	Alternate Horn Selection	Status Report	Heavy Load (Shut Down)	Mute	Squealing Brakes Air Brakes (Cylinder Cocks)	Doppler Shift	Dynamic Brakes	Blower Hiss/Fans	Coupler	Horn/Whistle	Bell	Directional Lighting	Directional Lighting
	Outputs	14	13	12	11	10	9	8	7	6	5	4	3	2	1
33	FL(f)							0	0	0	0	0	0	1	1
34	FL(r)							0	0	0	0	0	0	1	1
35	Function 1							0	0	0	0	0	1	0	0
36	Function 2							0	0	0	0	1	0	0	0
37	Function 3							0	0	0	1	0	0	0	0
38	Function 4				0	0	0	0	0	1	0	0			
39	Function 5				0	0	0	0	1	0	0	0			
40	Function 6				0	0	0	1	0	0	0	0			
41	Function 7				0	0	1	0	0	0	0	0			
42	Function 8				0	1	0	0	0	0	0	0			
43	Function 9	0	0	0	1	0	0	0	0						
44	Function 10	0	0	1	0	0	0	0	0						
45	Function 11	0	1	0	0	0	0	0	0						
46	Function 12	1	0	0	0	0	0	0	0						

[45] Q2 firmware built after 1-June-08 does not support CV's 33-46.

46 Some earlier command stations only support the original NMRA specification of 10 functions using 9 Function Keys.

47 For Command Stations that do not have an FL key, the F0 Function key usually controls this function.

A “1” with light gray background shows the Output default settings for Quantum decoders. For example, CV 36 has a “1” in the column for Output 4, indicating that Function 2 controls Output 4 which will operate the Whistle or Horn.

Each Input Function can control up to 8 Outputs. The white squares in the table show allowed possible assignments of Outputs for each Function. The dark gray areas indicate where Outputs cannot be assigned. For instance, the F4 key (Function Input 4) can control only Outputs 4-11. You can chose to have the F4 Key operate Output 10 or a combination of Outputs 11, 9, 7, and 6 all at once, but you cannot have it operate Output 12.

For many non-sound decoders, the Outputs are literally wires that are connected to different features such as Headlights and Reverse Lights, overhead blinking lights, smoke generators, and couplers. All the Outputs are “hardwired” to the features, meaning you cannot change which feature corresponds to an Output without rewiring the features.

For Sound Decoders like the first Quantum System, only some of the Outputs were “hardwired” to a particular feature. Many of the features require no external wires. Examples of these internal features are bells, whistles, air let-offs, blower hiss, and flange sounds.

On modern decoders, even those features that do require external wires, such as lights and smoke generators, are not necessarily “hardwired” to any particular Output. Outputs are now virtual and can be connected internally by firmware in the Quantum microprocessor to any physical driver, such as a power output for a lamp or a controller for a smoke generator. The connection between a virtual output and a physical feature is called a control port or simply “port”. For consistency with NMRA definitions, virtual outputs are called simply “outputs”.

A virtual output can be connected to more than one port. For example, the Multiple Automatic Lights #1 virtual output is by default connected to the Headlight, Reverse Light, and in some models a Mars Light.

Virtual outputs can be connected to different features depending on the directional state of the locomotive. For example, Output 8 is assigned to Doppler Shift in Forward and Reverse but is assigned to “Locomotive Start Up” in Neutral.

Both of these techniques increase the number of features that can be operated with a limited number of function keys.

The above table shows Common Default Quantum Features Assignments in the second row. Features assignments that operate only in Neutral are shown in parenthesis under the feature that operates in Forward and Reverse. If no Neutral feature is shown, the assigned feature shown will operate in all directional states.

Features are assigned to outputs in CV 53.

Advanced Sound Decoders like the Quantum Decoders allow great flexibility in choosing which function keys operate which features. However, this flexibility can get you into trouble if misused. For technical reasons too complicated to discuss here[48], we recommend you follow the two rules below to avoid having your decoder behave in a confusing manner.

1. In CV’s 33-46, do not attempt to control the same Output with two or more function keys. This means, in the table above, only one row in each column should have a “1”. Yes, we violated this rule for Output 1 and Output 2, where we have both FL(f) and FL(r) operating the Directional Lighting System. This is an exception, which does work for Directional Lighting using FL(f) and FL(r). In general, it is not a good idea.
2. In CV 53, do not assign the same feature to two or more Outputs.

48 See Appendix VI Interaction of Function Keys, Function Groups, Function Inputs and Outputs and Feature Assignments for additional technical explanation.

4.2 CV 33 Output Location for FL(f)[49]

This CV specifies whether outputs 1 thru 8 are controlled by FL(f).

A '1' in a bit location specifies the output is controlled by FL(f), while a '0' specifies the output is not controlled by FL(f).

Default Value: **00000011 = 3**

CV 33: Output Location for FL(f) (with Factory Default Features)

Doppler (Start Up)	Dynamic Brakes	Blower-Hiss/Fans	Coupler Crash Coupler Fire (Coupler Arm)	Horn/Whistle	Bell	Directional Lighting[50]	Directional Lighting
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Output 8	**Output 7**	**Output 6**	**Output 5**	**Output 4**	**Output 3**	**Output 2**	**Output 1**

- QSI has pre-assigned default features to each output but any feature can be assigned to any output in CV 53. In CV 53, the default setting for Outputs 1 and 2 is the Directional Lighting System. Therefore, by default FL(f) controls the Directional Lighting System in Forward or Neutral from Forward.
- You can specify that FL(f) controls any of Outputs 2 thru 8 in addition to or instead of Outputs 1 and 2.
- Assuming the default CV 53 settings (shown in the top row)[51], you can specify that FL(f) controls the following features.

Bit 0 Output 1: Directional Lighting

"0" The Directional Lighting System is unaffected by FL(f).
"1" The Directional Lighting System is affected by FL(f).

Bit 1 Output 2: Directional Lighting

"0" The Directional Lighting System is unaffected by FL(f).
"1" The Directional Lighting System is affected by FL(f).

Bit 2 Output 3; Bell

"0" The Bell is unaffected by FL(f).
"1" The Bell is affected by FL(f).

Bit 3 Output 4; Horn/Whistle

"0" The Horn/Whistle is unaffected by FL(f).
"1" Horn/Whistle is affected by FL(f).

49 Write bit operation is supported for CV 33.
50 The lights used in Directional Lighting are selected in Multiple Lights #1, which is the actual feature assigned to Outputs 1 and 2 (see CV55.136). Depending on your model, different lights may be selected for Multiple Lights #1.
51 Features that are different in the Neutral state are shown in parentheses

Bit 4 Output 5: Coupler Crash, Coupler Arm, Coupler Fire

"0" The Coupler Sounds are unaffected by FL(f).
"1" The Coupler Sounds are affected by FL(f).

Bit 5 Output 6: Steam Locomotive Blower Hiss or Diesel or Electric Loco Vents and Fans

"0" Blower-Hiss/Fans are unaffected by FL(f).
"1" Blower-Hiss/Fans are affected by FL(f).

Bit 6 Output 7: Dynamic Brakes

"0" Dynamic Brakes are unaffected by FL(f).
"1" Dynamic Brakes are affected by FL(f).

Bit 7 Output 8: Doppler, Start Up

"0" Doppler shift in Forward/Reverse and Start up in Neutral are unaffected by FL(f).
"1" Doppler shift in Forward/Reverse and Start up in Neutral are affected by FL(f).

4.3 CV 34 Output Location for FL(r)[52]

This CV specifies whether outputs 1 thru 8 are controlled by FL(r).

A '1' in a bit location specifies the output is controlled by FL(r), while a '0' specifies the output is not controlled by FL(r).

Default Value: **00000011 = 3**

CV 34: Output Location for FL(r) (with Factory Default Features)

Doppler (Start Up)	Dynamic Brakes	Blower-Hiss/Fans	Coupler Crash Coupler Fire (Coupler Arm)	Horn/Whistle	Bell	Directional Lighting[53]	Directional Lighting
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Output 8	**Output 7**	**Output 6**	**Output 5**	**Output 4**	**Output 3**	**Output 2**	**Output 1**

- QSI has pre-assigned default features to each output but any feature can be assigned to any output in CV 53. In CV 53, the default setting for Outputs 1 and 2 is the Directional Lighting System. Therefore, by default FL(r) controls the Directional Lighting System in Reverse or Neutral from Reverse.
- You can specify that FL(r) control any of Outputs 3 thru 8 in addition to or instead of Outputs 1 and 2.
- Assuming the default CV 53 settings (shown in the top row)[54], you can specify that FL(r) control the following features.

Bit 0 Output 1: Directional Lighting

"0" The Directional Lighting System is unaffected by FL(r).
"1" The Directional Lighting System is affected by FL(r).

Bit 1 Output 2: Directional Lighting

"0" The Directional Lighting System is unaffected by FL(r).
"1" The Directional Lighting System is affected by FL(r).

Bit 2 Output 3; Bell

"0" The Bell is unaffected by FL(r).
"1" The Bell is affected by FL(r).

Bit 3 Output 4; Horn/Whistle

"0" The Horn/Whistle is unaffected by FL(r).
"1" Horn/Whistle is affected by FL(r).

52 Write bit operation is supported for CV 34.
53 The lights used in Directional Lighting are selected in Multiple Lights #1, which is the actual feature assigned to Outputs 1 and 2 (see CV55.136). Depending on your model, different lights may be selected for Multiple Lights #1.
54 Features that are different in the Neutral state are shown in parentheses

Bit 4 Output 5: Coupler Crash, Coupler Arm, Coupler Fire

"0" The Coupler Sounds are unaffected by FL(r).
"1" The Coupler Sounds are affected by FL(r).

Bit 5 Output 6: Steam Locomotive Blower Hiss or Diesel or Electric Loco Vents and Fans

"0" Blower-Hiss/Fans are unaffected by FL(r).
"1" Blower-Hiss/Fans are affected by FL(r).

Bit 6 Output 7: Dynamic Brakes

"0" Dynamic Brakes are unaffected by FL(r).
"1" Dynamic Brakes are affected by FL(r).

Bit 7 Output 8: Doppler, Start Up

"0" Doppler shift in Forward/Reverse and Start up in Neutral are unaffected by FL(r).
"1" Doppler shift in Forward/Reverse and Start up in Neutral are affected by FL(r).

4.4 CV 35 Output Location for F1[55]

This CV specifies whether outputs 1 thru 8 are controlled by F1.

A '1' in a bit location specifies the output is controlled by F1, while a '0' specifies the output is not controlled by F1.

Default Value: **00000100 = 4**

CV 35: Output for F1 (with Factory Default Features)

Doppler (Start Up)	Dynamic Brakes	Blower-Hiss/Fans	Coupler Crash Coupler Fire (Coupler Arm)	Horn/Whistle	Bell	Directional Lighting[56]	Directional Lighting
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Output 8	**Output 7**	**Output 6**	**Output 5**	**Output 4**	**Output 3**	**Output 2**	**Output 1**

- QSI has pre-assigned default features to each output but any feature can be assigned to any output in CV 53. In CV 53, the default setting for Output 3 is the Bell. Therefore, by default F1 controls the Bell.
- You can specify that F1 control any of Outputs 1-2 and 4-8 in addition to or instead of Output 3.
- Assuming the default CV 53 settings (shown in the top row)[57], you can specify that F1 control the following features.

Bit 0 Output 1: Directional Lighting

"0" The Directional Lighting System is unaffected by F1.
"1" The Directional Lighting System is affected by F1.

Bit 1 Output 2: Directional Lighting

"0" The Directional Lighting System is unaffected by F1.
"1" The Directional Lighting System is affected by F1.

Bit 2 Output 3; Bell

"0" The Bell is unaffected by F1.
"1" The Bell is affected by F1.

Bit 3 Output 4; Horn/Whistle

"0" The Horn/Whistle is unaffected by F1.
"1" Horn/Whistle is affected by F1.

55 Write bit operation is supported for CV 35.
56 The lights used in Directional Lighting are selected in Multiple Lights #1, which is the actual feature assigned to Outputs 1 and 2 (see CV55.136). Depending on your model, different lights may be selected for Multiple Lights #1.
57 Features that are different in the Neutral state are shown in parentheses

Bit 4 Output 5: Coupler Crash, Coupler Arm, Coupler Fire

"0" The Coupler Sounds are unaffected by F1.
"1" The Coupler Sounds are affected by F1.

Bit 5 Output 6: Steam Locomotive Blower Hiss or Diesel or Electric Loco Vents and Fans

"0" Blower-Hiss/Fans are unaffected by F1.
"1" Blower-Hiss/Fans are affected by F1.

Bit 6 Output 7: Dynamic Brakes

"0" Dynamic Brakes are unaffected by F1.
"1" Dynamic Brakes are affected by F1.

Bit 7 Output 8: Doppler, Start Up

"0" Doppler shift in Forward/Reverse and Start up in Neutral are unaffected by F1.
"1" Doppler shift in Forward/Reverse and Start up in Neutral are affected by F1.

4.5 CV 36 Output Location for F2[58]

This CV specifies whether outputs 1 thru 8 are controlled by F2.

A '1' in a bit location specifies the output is controlled by F2, while a '0' specifies the output is not controlled by F2.

Default Value: **00001000 = 8**

CV 36: Output Location for F2 (with Factory Default Features)

Doppler (Start Up)	Dynamic Brakes	Blower-Hiss/Fans	Coupler Crash Coupler Fire (Coupler Arm)	Horn/Whistle	Bell	Directional Lighting[59]	Directional Lighting
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Output 8	**Output 7**	**Output 6**	**Output 5**	**Output 4**	**Output 3**	**Output 2**	**Output 1**

- QSI has pre-assigned default features to each output but any feature can be assigned to any output in CV 53. In CV 53, the default setting for Output 4 is the Whistle or Horn. Therefore, by default F2 controls the Whistle or Horn while locomotive is moving or stopped.
- You can specify that F1 control any of Outputs 1-3 and 5-8 in addition to or instead of Output 4.
- Assuming the default CV 53 settings (shown in the top row)[60], you can specify that F2 control the following features.

Bit 0 Output 1: Directional Lighting

"0" The Directional Lighting System is unaffected by F2.
"1" The Directional Lighting System is affected by F2.

Bit 1 Output 2: Directional Lighting

"0" The Directional Lighting System is unaffected by F2.
"1" The Directional Lighting System is affected by F2.

Bit 2 Output 3; Bell

"0" The Bell is unaffected by F2.
"1" The Bell is affected by F2.

Bit 3 Output 4; Horn/Whistle

"0" The Horn/Whistle is unaffected by F2.
"1" Horn/Whistle is affected by F2.

58 Write bit operation is supported for CV 36.
59 The lights used in Directional Lighting are selected in Multiple Lights #1, which is the actual feature assigned to Outputs 1 and 2 (see CV55.136). Depending on your model, different lights may be selected for Multiple Lights #1.
60 Features that are different in the Neutral state are shown in parentheses

Bit 4 Output 5: Coupler Crash, Coupler Arm, Coupler Fire

"0" The Coupler Sounds are unaffected by F2.
"1" The Coupler Sounds are affected by F2.

Bit 5 Output 6: Steam Locomotive Blower Hiss or Diesel or Electric Loco Vents and Fans

"0" Blower-Hiss/Fans are unaffected by F2.
"1" Blower-Hiss/Fans are affected by F2.

Bit 6 Output 7: Dynamic Brakes

"0" Dynamic Brakes are unaffected by F2.
"1" Dynamic Brakes are affected by F2.

Bit 7 Output 8: Doppler, Start Up

"0" Doppler shift in Forward/Reverse and Start up in Neutral are unaffected by F2.
"1" Doppler shift in Forward/Reverse and Start up in Neutral are affected by F2.

4.6 CV 37 Output Location for F3[61]

This CV specifies whether outputs 1 thru 8 are controlled by F3.

A '1' in a bit location specifies the output is controlled by F3, while a '0' specifies the output is not controlled by F3.

Default Value: **00010000 = 16**

CV 37: Output Location for F3 (with Factory Default Features)

Doppler (Start Up)	Dynamic Brakes	Blower-Hiss/Fans	Coupler Crash Coupler Fire (Coupler Arm)	Horn/Whistle	Bell	Directional Lighting[62]	Directional Lighting
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Output 8	**Output 7**	**Output 6**	**Output 5**	**Output 4**	**Output 3**	**Output 2**	**Output 1**

- QSI has pre-assigned default features to each output but any feature can be assigned to any output in CV 53. In CV 53, the default setting for Output 5 is the Coupler Crash, Coupler Fire and Coupler Arm. Therefore, by default F3 controls the Coupler Sounds.
- You can specify that F3 control any of Outputs 1-4 and 6-8 in addition to or instead of Output 5.
- Assuming the default CV 53 settings (shown in the top row)[63], you can specify that F3 control the following features.

Bit 0 Output 1: Directional Lighting

"0" The Directional Lighting System is unaffected by F3.
"1" The Directional Lighting System is affected by F3.

Bit 1 Output 2: Directional Lighting

"0" The Directional Lighting System is unaffected by F3.
"1" The Directional Lighting System is affected by F3.

Bit 2 Output 3; Bell

"0" The Bell is unaffected by F3.
"1" The Bell is affected by F3.

Bit 3 Output 4; Horn/Whistle

"0" The Horn/Whistle is unaffected by F3.
"1" Horn/Whistle is affected by F3.

61 Write bit operation is supported for CV 37.
62 The lights used in Directional Lighting are selected in Multiple Lights #1, which is the actual feature assigned to Outputs 1 and 2 (see CV55.136). Depending on your model, different lights may be selected for Multiple Lights #1.
63 Features that are different in the Neutral state are shown in parentheses

Bit 4 Output 5: Coupler Crash, Coupler Arm, Coupler Fire

"0" The Coupler Sounds are unaffected by F3.
"1" The Coupler Sounds are affected by F3.

Bit 5 Output 6: Steam Locomotive Blower Hiss or Diesel or Electric Loco Vents and Fans

"0" Blower-Hiss/Fans are unaffected by F3.
"1" Blower-Hiss/Fans are affected by F3.

Bit 6 Output 7: Dynamic Brakes

"0" Dynamic Brakes are unaffected by F3.
"1" Dynamic Brakes are affected by F3.

Bit 7 Output 8: Doppler, Start Up

"0" Doppler shift in Forward/Reverse and Start up in Neutral are unaffected by F3.
"1" Doppler shift in Forward/Reverse and Start up in Neutral are affected by F3.

Example: Change F3 to Bell Operation (Output 3), and change F1 to Coupler Sounds (Output 5).
Output 3 is set to Bell by default. Output 5 is set to Coupler Sounds by default.
Set CV 37 (F3) to "4" (bit 2 = output 3 = Bell)
Set CV 35 (F1) to "16" (bit 4 = output 5 = Coupler Sounds)
After these changes, F3 will activate the bell, and F1 will activate Coupler Sounds**.**

4.7 CV 38 Output Location for F4[64]

This CV specifies whether outputs 4 thru 11 are controlled by F4.

A '1' in a bit location specifies the output is controlled by F4, while a '0' specifies the output is not controlled by F4.

Default Value: **00000100 = 4**

CV 38: Output Location for F4 Register (with Factory Default Features)

Heavy Load (Disconnect-Standby-Shut Down)	Mute	Squealing Brakes/Flanges /Air Brakes (Cylinder Cocks/ Long Air Let-Off)	Doppler (Start Up)	Dynamic Brakes	Blower-Hiss/Fans	Coupler Crash Coupler Fire (Coupler Arm)	Horn/Whistle
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Output 11	**Output 10**	**Output 9**	**Output 8**	**Output 7**	**Output 6**	**Output 5**	**Output 4**

- QSI has pre-assigned default features to each output but any feature can be assigned to any output in CV 53. In CV 53, the default setting for Output 6 is Blower Hiss/Fans. Therefore, by default F4 controls the Blower Hiss/Fans Sound.
- You can specify that F4 control any of Outputs 4-5 and 7-11 in addition to or instead of Output 6.
- Assuming the default CV 53 settings (shown in the top row)[65], you can specify that F4 control the following features.

Bit 0 Output 4; Horn/Whistle

"0" The Horn/Whistle is unaffected by F4.
"1" Horn/Whistle is affected by F4.

Bit 1 Output 5: Coupler Crash, Coupler Arm, Coupler Fire

"0" The Coupler Sounds are unaffected by F4.
"1" The Coupler Sounds are affected by F4.

Bit 2 Output 6: Steam Locomotive Blower Hiss or Diesel or Electric Loco Vents and Fans

"0" Blower-Hiss/Fans are unaffected by F4.
"1" Blower-Hiss/Fans are affected by F4.

Bit 3 Output 7: Dynamic Brakes

"0" Dynamic Brakes are unaffected by F4.
"1" Dynamic Brakes are affected by F4.

Bit 4 Output 8: Doppler, Start Up

"0" Doppler shift in Forward/Reverse and Start up in Neutral are unaffected by F4.
"1" Doppler shift in Forward/Reverse and Start up in Neutral are affected by F4.

64 Write bit operation is supported for CV 38.
65 Features that are different in the Neutral state are shown in parentheses

Bit 5 Output 9: Squealing Brakes and Air Brakes, Cylinder Cocks Arm or Long Air Let-off

"0" Squealing Brakes, Air Brakes in Forward/Reverse and Cylinder Cocks Arm, Long Air Let-off are unaffected by F4.

"1" Squealing Brakes, Air Brakes in Forward/Reverse and Cylinder Cocks Arm, Long Air Let-off are affected by F4.

Bit 6 Output 10: Audio Mute

"0" Audio Mute is unaffected by F4.

"1" Audio Mute is affected by F4.

Bit 7 Output 11: Heavy Load, Disconnect-Standby-Total Shut Down

"0" Heavy Load in Forward/Reverse and Disconnect-Standby-Total Shut Down in Neutral are unaffected by F4.

"1" Heavy Load in Forward/Reverse and Disconnect-Standby-Total Shut Down in Neutral are affected by F4.

Note: Heavy Load has replaced the Cruise Control feature that was available on Lionel HO and early BLI locomotives.

4.8 CV 39 Output Location for F5[66]

This CV specifies whether outputs 4 thru 11 are controlled by F5.

A '1' in a bit location specifies the output is controlled by F5, while a '0' specifies the output is not controlled by F5.

Default Value: **00001000 = 8**

CV 39: Output Location for F5 Register (with Factory Default Features)

Heavy Load (Disconnect-Standby-Total Shut Down)	Mute	Squealing Brakes/Flanges /Air Brakes (Cylinder Cocks/ Long Air Let-Off	Doppler (Start Up)	Dynamic Brakes	Blower-Hiss/Fans	Coupler Crash Coupler Fire (Coupler Arm)	Horn/Whistle
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Output 11	**Output 10**	**Output 9**	**Output 8**	**Output 7**	**Output 6**	**Output 5**	**Output 4**

- QSI has pre-assigned default features to each output but any feature can be assigned to any output in CV 53. In CV 53, the default setting for Output 7 is Dynamic Brakes. Therefore, by default F5 controls the Dynamic Brake Sounds.
- You can specify that F5 control any of Outputs 4-6 and 8-11 in addition to or instead of Output 7.
- Assuming the default CV 53 settings (shown in the top row)[67], you can specify that F5 control the following features.

Bit 0 Output 4; Horn/Whistle

"0" The Horn/Whistle is unaffected by F5.
"1" Horn/Whistle is affected by F5.

Bit 1 Output 5: Coupler Crash, Coupler Arm, Coupler Fire

"0" The Coupler Sounds are unaffected by F5.
"1" The Coupler Sounds are affected by F5.

Bit 2 Output 6: Steam Locomotive Blower Hiss or Diesel or Electric Loco Vents and Fans

"0" Blower-Hiss/Fans are unaffected by F5.
"1" Blower-Hiss/Fans are affected by F5.

Bit 3 Output 7: Dynamic Brakes

"0" Dynamic Brakes are unaffected by F5.
"1" Dynamic Brakes are affected by F5.

Bit 4 Output 8: Doppler, Start Up

"0" Doppler shift in Forward/Reverse and Start up in Neutral are unaffected by F5.
"1" Doppler shift in Forward/Reverse and Start up in Neutral are affected by F5.

66 Write bit operation is supported for CV 39.
67 Features that are different in the Neutral state are shown in parentheses

Bit 5 Output 9: Squealing Brakes and Air Brakes, Cylinder Cocks Arm or Long Air Let-off

"0" Squealing Brakes, Air Brakes in Forward/Reverse and Cylinder Cocks Arm, Long Air Let-off are unaffected by F5.

"1" Squealing Brakes, Air Brakes in Forward/Reverse and Cylinder Cocks Arm, Long Air Let-off are affected by F5.

Bit 6 Output 10: Audio Mute

"0" Audio Mute is unaffected by F5.

"1" Audio Mute is affected by F5.

Bit 7 Output 11: Heavy Load, Disconnect-Standby-Total Shut Down

"0" Heavy Load in Forward/Reverse and Disconnect-Standby-Total Shut Down in Neutral are unaffected by F5.

"1" Heavy Load in Forward/Reverse and Disconnect-Standby-Total Shut Down in Neutral are affected by F5.

Note: Heavy Load has replaced the Cruise Control feature that was available on Lionel HO and early BLI locomotives.

4.9 CV 40 Output Location for F6[68]

This CV specifies whether outputs 4 thru 11 are controlled by F6.

A '1' in a bit location specifies the output is controlled by F6, while a '0' specifies the output is not controlled by F6.

Default Value: **00010000 = 16**

CV 40: F6 Output Location for F6 Register (with Factory Default Features)

Heavy Load (Disconnect-Standby-Total Shut Down)	Mute	Squealing Brakes/Flanges /Air Brakes (Cylinder Cocks/ Long Air Let-Off	Doppler (Start Up)	Dynamic Brakes	Blower-Hiss/Fans	Coupler Crash Coupler Fire (Coupler Arm)	Horn/Whistle
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Output 11	**Output 10**	**Output 9**	**Output 8**	**Output 7**	**Output 6**	**Output 5**	**Output 4**

- QSI has pre-assigned default features to each output but any feature can be assigned to any output in CV 53. In CV 53, the default settings for Output 8 are Doppler Shift for a moving locomotive and Locomotive Start Up in Neutral. Therefore, by default F6 controls Doppler Shift and Start Up.
- You can specify that F6 control any of Outputs 4-7 and 9-11 in addition to or instead of Output 8.
- Assuming the default CV 53 settings (shown in the top row)[69], you can specify that F6 control the following features.

Bit 0 Output 4; Horn/Whistle

"0" The Horn/Whistle is unaffected by F6.
"1" Horn/Whistle is affected by F6.

Bit 1 Output 5: Coupler Crash, Coupler Arm, Coupler Fire

"0" The Coupler Sounds are unaffected by F6.
"1" The Coupler Sounds are affected by F6.

Bit 2 Output 6: Steam Locomotive Blower Hiss or Diesel or Electric Loco Vents and Fans

"0" Blower-Hiss/Fans are unaffected by F6.
"1" Blower-Hiss/Fans are affected by F6.

Bit 3 Output 7: Dynamic Brakes

"0" Dynamic Brakes are unaffected by F6.
"1" Dynamic Brakes are affected by F6.

Bit 4 Output 8: Doppler, Start Up

"0" Doppler shift in Forward/Reverse and Start up in Neutral are unaffected by F6.
"1" Doppler shift in Forward/Reverse and Start up in Neutral are affected by F6.

68 Write bit operation is supported for CV 40.
69 Features that are different in the Neutral state are shown in parentheses

Bit 5 Output 9: Squealing Brakes and Air Brakes, Cylinder Cocks Arm or Long Air Let-off.

"0" Squealing Brakes, Air Brakes in Forward/Reverse and Cylinder Cocks Arm, Long Air Let-off are unaffected by F6.

"1" Squealing Brakes, Air Brakes in Forward/Reverse and Cylinder Cocks Arm, Long Air Let-off are affected by F6.

Bit 6 Output 10: Audio Mute

"0" Audio Mute is unaffected by F6.

"1" Audio Mute is affected by F6.

Bit 7 Output 11: Heavy Load, Disconnect-Standby-Total Shut Down

"0" Heavy Load in Forward/Reverse and Disconnect-Standby-Total Shut Down in Neutral are unaffected by F6.

"1" Heavy Load in Forward/Reverse and Disconnect-Standby-Total Shut Down in Neutral are affected by F6.

Note: Heavy Load has replaced the Cruise Control feature that was available on Lionel HO and early BLI locomotives.

4.10 CV 41 Output Location for F7[70]

This CV specifies whether outputs 4 thru 11 are controlled by F7.

A '1' in a bit location specifies the output is controlled by F7, while a '0' specifies the output is not controlled by F7.

Default Value: **00100000 = 32**

CV 41: Output Location for F7 Register (with Factory Default Features)

Heavy Load (Disconnect-Standby-Total Shut Down)	Mute	Squealing Brakes/Flanges /Air Brakes (Cylinder Cocks/ Long Air Let-Off	Doppler (Start Up)	Dynamic Brakes	Blower-Hiss/Fans	Coupler Crash Coupler Fire (Coupler Arm)	Horn/Whistle
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Output 11	**Output 10**	**Output 9**	**Output 8**	**Output 7**	**Output 6**	**Output 5**	**Output 4**

- QSI has pre-assigned default features to each output but any feature can be assigned to any output in CV 53. In CV 53, the default settings for Output 9 are Squealing Brakes plus Air Brakes for a moving locomotive and Cylinder Cocks Arm or a Long Air Let-off for a Brake Set in Neutral. Therefore, by default F7 controls Squealing Brakes or Air Brakes for a moving locomotive and a Cylinder Cocks Arm or Brake Set Sound in Neutral.
- You can specify that F7 control any of Outputs 4-8 and 10-11 in addition to or instead of Output 9.
- Assuming the default CV 53 settings (shown in the top row)[71], you can specify that F7 control the following features.

Bit 0 Output 4; Horn/Whistle

"0" The Horn/Whistle is unaffected by F7.
"1" Horn/Whistle is affected by F7.

Bit 1 Output 5: Coupler Crash, Coupler Arm, Coupler Fire

"0" The Coupler Sounds are unaffected by F7.
"1" The Coupler Sounds are affected by F7.

Bit 2 Output 6: Steam Locomotive Blower Hiss or Diesel or Electric Loco Vents and Fans

"0" Blower-Hiss/Fans are unaffected by F7.
"1" Blower-Hiss/Fans are affected by F7.

Bit 3 Output 7: Dynamic Brakes

"0" Dynamic Brakes are unaffected by F7.
"1" Dynamic Brakes are affected by F7.

Bit 4 Output 8: Doppler, Start Up

"0" Doppler shift in Forward/Reverse and Start up in Neutral are unaffected by F7.
"1" Doppler shift in Forward/Reverse and Start up in Neutral are affected by F7.

70 Write bit operation is supported for CV 41.
71 Features that are different in the Neutral state are shown in parentheses

Bit 5 Output 9: Squealing Brakes and Air Brakes, Cylinder Cocks Arm or Long Air Let-off

"0" Squealing Brakes, Air Brakes in Forward/Reverse and Cylinder Cocks Arm, Long Air Let-off are unaffected by F7.

"1" Squealing Brakes, Air Brakes in Forward/Reverse and Cylinder Cocks Arm, Long Air Let-off are affected by F7.

Bit 6 Output 10: Audio Mute or

"0" Audio Mute is unaffected by F7.

"1" Audio Mute is affected by F7.

Bit 7 Output 11: Heavy Load, Disconnect-Standby-Total Shut Down

"0" Heavy Load in Forward/Reverse and Disconnect-Standby-Total Shut Down in Neutral are unaffected by F7.

"1" Heavy Load in Forward/Reverse and Disconnect-Standby-Total Shut Down in Neutral are affected by F7.

Note: Heavy Load has replaced the Cruise Control feature that was available on Lionel HO and early BLI locomotives.

4.11 CV 42 Output Location for F8[72]

This CV specifies whether outputs 4 thru 11 are controlled by F8.

A '1' in a bit location specifies the output is controlled by F8, while a '0' specifies the output is not controlled by F8.

Default Value: **01000000 = 64**

CV 42: Output Location for F8 Register (with Factory Default Features)

Heavy Load (Disconnect-Standby-Total Shut Down)	Mute	Squealing Brakes/Flanges /Air Brakes (Cylinder Cocks/ Long Air Let-Off	Doppler (Start Up)	Dynamic Brakes	Blower-Hiss/Fans	Coupler Crash Coupler Fire (Coupler Arm)	Horn/Whistle
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Output 11	**Output 10**	**Output 9**	**Output 8**	**Output 7**	**Output 6**	**Output 5**	**Output 4**

- QSI has pre-assigned default features to each output but any feature can be assigned to any output in CV 53. In CV 53, the default setting for Output 10 is Audio Mute. Therefore, by default F8 controls Audio Mute.
- You can specify that F8 control any of Outputs 4-9 and 11 in addition to or instead of Output 10.
- Assuming the default CV 53 settings (shown in the top row)[73], you can specify that F8 control the following features.

Bit 0 Output 4; Horn/Whistle

"0" The Horn/Whistle is unaffected by F8.
"1" Horn/Whistle is affected by F8.

Bit 1 Output 5: Coupler Crash, Coupler Arm, Coupler Fire

"0" The Coupler Sounds are unaffected by F8.
"1" The Coupler Sounds are affected by F8.

Bit 2 Output 6: Steam Locomotive Blower Hiss or Diesel or Electric Loco Vents and Fans

"0" Blower-Hiss/Fans are unaffected by F8.
"1" Blower-Hiss/Fans are affected by F8.

Bit 3 Output 7: Dynamic Brakes

"0" Dynamic Brakes are unaffected by F8.
"1" Dynamic Brakes are affected by F8.

Bit 4 Output 8: Doppler, Start Up

"0" Doppler shift in Forward/Reverse and Start up in Neutral are unaffected by F8.
"1" Doppler shift in Forward/Reverse and Start up in Neutral are affected by F8.

72 Write bit operation is supported for CV 42.
73 Features that are different in the Neutral state are shown in parentheses

Bit 5 Output 9: Squealing Brakes and Air Brakes, Cylinder Cocks Arm or Long Air Let-off

"0" Squealing Brakes, Air Brakes in Forward/Reverse and Cylinder Cocks Arm, Long Air Let-off are unaffected by F8.

"1" Squealing Brakes, Air Brakes in Forward/Reverse and Cylinder Cocks Arm, Long Air Let-off are affected by F8.

Bit 6 Output 10: Audio Mute

"0" Audio Mute is unaffected by F8.

"1" Audio Mute is affected by F8.

Bit 7 Output 11: Heavy Load, Disconnect-Standby-Total Shut Down

"0" Heavy Load in Forward/Reverse and Disconnect-Standby-Total Shut Down in Neutral are unaffected by F8.

"1" Heavy Load in Forward/Reverse and Disconnect-Standby-Total Shut Down in Neutral are affected by F8.

Note: Heavy Load has replaced the Cruise Control feature that was available on Lionel HO and early BLI locomotives.

4.12 CV 43 Output Location for F9[74]

This CV specifies whether outputs 7 thru 14 are controlled by F9.

A '1' in a bit location specifies the output is controlled by F9, while a '0' specifies the output is not controlled by F9.

Default Value: **00010000 = 16**

CV 43: Output Location for F9 Register (with Factory Default Features)

Cab Lights[75]	Alternate Horn Selection[76]/ Number Board Lights[77]	SMPH Report (Status Report)	Heavy Load (Disconnect-Standby-Total Shut Down)	Mute	Squealing Brakes/Flanges /Air Brakes (Cylinder Cocks/ Long Air Let-Off	Doppler (Start Up)	Dynamic Brakes
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Output 14	**Output 13**	**Output 12**	**Output 11**	**Output 10**	**Output 9**	**Output 8**	**Output 7**

- QSI has pre-assigned default features to each output but any feature can be assigned to any output in CV 53. In CV 53, the default settings for Output 11 are Heavy Load for a moving locomotive and Disconnect-Standby-Shut Down for a locomotive in Neutral. Therefore, by default F9 controls Heavy Load and Disconnect-Standby-Shut Down.

  Note: Heavy Load has replaced the Cruise Control feature that was available on Lionel HO and early BLI locomotives.

- You can specify that F9 control any of Outputs 7-10 and 12-14 in addition to or instead of Output 11.
- Assuming the default CV 53 settings (shown in the top row)[78], you can specify that F9 control the following features.

Bit 0 Output 7: Dynamic Brakes

"0" Dynamic Brakes are unaffected by F9.
"1" Dynamic Brakes are affected by F9.

Bit 1 Output 8: Doppler, Start Up

"0" Doppler shift in Forward/Reverse and Start up in Neutral are unaffected by F9.
"1" Doppler shift in Forward/Reverse and Start up in Neutral are affected by F9.

Bit 2 Output 9: Squealing Brakes and Air Brakes, Cylinder Cocks Arm or Long Air Let-off

"0" Squealing Brakes, Air Brakes in Forward/Reverse and Cylinder Cocks Arm, Long Air Let-off are unaffected by F9.
"1" Squealing Brakes, Air Brakes in Forward/Reverse and Cylinder Cocks Arm, Long Air Let-off are affected by F9.

74 Write bit operation is supported for CV 43.
75 Cab Lights are usually selected by default in Multiple Lights #3, which is the actual feature assigned to Output 14 (see CV 55.138). Depending on your model, different lights may be selected for Multiple Lights #3.
76 Alternate Horn is available only on selected models. Consult your Model's Operation Manual feature list.
77 Number Board Lights are usually selected by default in Multiple Lights #2, which is the actual feature assigned to Output 13 (see CV 55.137). Depending on your model, different lights may be selected for Multiple Lights #2.
78 Features that are different in the Neutral state are shown in parentheses

Bit 3 Output 10: Audio Mute

"0" Audio Mute is unaffected by F9.
"1" Audio Mute is affected by F9.

Bit 4 Output 11: Heavy Load, Disconnect-Standby-Total Shut Down

"0" Heavy Load in Forward/Reverse and Disconnect-Standby-Total Shut Down in Neutral are unaffected by F9.
"1" Heavy Load in Forward/Reverse and Disconnect-Standby-Total Shut Down in Neutral are affected by F9.

Note: Heavy Load has replaced the Cruise Control feature that was available on Lionel HO and early BLI locomotives.

Bit 5 Output 12: Speed Report, Status Report

"0" Speed Report in Forward/Reverse and Status Report in Neutral are unaffected by F9.
"1" Speed Report in Forward/Reverse and Status Report in Neutral are unaffected by F9.

Bit 6 Output 13: Number Board Lights

"0" Alternate Horn Selection or Number Board Lights are unaffected by F9.
"1" Alternate Horn Selection or Number Board Lights are affected by F9.

Bit 7 Output 14: Cab Lights

"0" Cab Lights are unaffected by F9.
"1" Cab Lights are affected by F9.

4.13 CV 44 Output Location for F10[79]

This CV specifies whether outputs 7 thru 14 are controlled by F10.

A '1' in a bit location specifies the output is controlled by F10, while a '0' specifies the output is not controlled by F10.

Default Value: **00100000 = 32**

CV 44: Output Location for F10 Register (with Factory Default Features)

Cab Lights[80]	Alternate Horn Selection[81]/ Number Board Lights[82]	Speed Report (Status Report)	Heavy Load (Disconnect-Standby-Total Shut Down)	Mute	Squealing Brakes – Air Brakes (Brake Set)	Doppler (Start Up)	Dynamic Brakes
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Output 14	**Output 13**	**Output 12**	**Output 11**	**Output 10**	**Output 9**	**Output 8**	**Output 7**

- QSI has pre-assigned default features to each output but any feature can be assigned to any output in CV 53. In CV 53, the default setting for Output 12 is a Scale Miles Per Hour (smph) or Scale Kilometers Per Hour (skph)[83] Speed Report in Forward/Reverse or Status Report in Neutral. Therefore F10 controls SMPH and Status Report.
- You can specify that F10 control any of Outputs 7-11 and 13-14 in addition to or instead of Output 12.
- Assuming the default CV 53 settings (shown in the top row)[84], you can specify that F10 control the following features.

Bit 0 Output 7: Dynamic Brakes

"0" Dynamic Brakes are unaffected by F10.
"1" Dynamic Brakes are affected by F10.

Bit 1 Output 8: Doppler, Start Up

"0" Doppler shift in Forward/Reverse and Start up in Neutral are unaffected by F10.
"1" Doppler shift in Forward/Reverse and Start up in Neutral are affected by F10.

79 Write bit operation is supported for CV 44.
80 Cab Lights are usually selected by default in Multiple Lights #3, which is the actual feature assigned to Output 14 (see CV 55.138). Depending on your model, different lights may be selected for Multiple Lights #3.
81 Alternate Horn is available only on selected models. Consult your Model's Operation Manual feature list.
82 Number Board Lights are usually selected by default in Multiple Lights #2, which is the actual feature assigned to Output 13 (see CV 55.137). Depending on your model, different lights may be selected for Multiple Lights #2.
83 Scale Miles Per Hour or Scale Kilometers Per Hour can be selected in CV 56.0.
84 Features that are different in the Neutral state are shown in parentheses

Bit 2 Output 9: Squealing Brakes and Air Brakes, Cylinder Cocks Arm or Long Air Let-off

"0" Squealing Brakes, Air Brakes in Forward/Reverse and Cylinder Cocks Arm, Long Air Let-off are unaffected by F10.
"1" Squealing Brakes, Air Brakes in Forward/Reverse and Cylinder Cocks Arm, Long Air Let-off are affected by F10.

Bit 3 Output 10: Audio Mute

"0" Audio Mute is unaffected by F10.
"1" Audio Mute is affected by F10.

Bit 4 Output 11: Heavy Load, Disconnect-Standby-Total Shut Down

"0" Heavy Load in Forward/Reverse and Disconnect-Standby-Total Shut Down in Neutral are unaffected by F10.
"1" Heavy Load in Forward/Reverse and Disconnect-Standby-Total Shut Down in Neutral are affected by F10.

Note: Heavy Load has replaced the Cruise Control feature that was available on Lionel HO and early BLI locomotives.

Bit 5 Output 12: Speed Report, Status Report

"0" Speed Report in Forward/Reverse and Status Report in Neutral are unaffected by F10.
"1" Speed Report in Forward/Reverse and Status Report in Neutral are unaffected by F10.

Bit 6 Output 13: Number Board Lights

"0" Alternate Horn Selection or Number Board Lights are unaffected by F10.
"1" Alternate Horn Selection or Number Board Lights are affected by F10.

Bit 7 Output 14: Cab Lights

"0" Cab Lights are unaffected by F10.
"1" Cab Lights are affected by F10.

4.14 CV 45 Output Location for F11[85]

This CV specifies whether outputs 7 thru 14 are controlled by F11.

A '1' in a bit location specifies the output is controlled by F11, while a '0' specifies the output is not controlled by F11.

Default Value: **01000000 = 64**

CV 45: Output Location for F11 Register (with Factory Default Features)

Cab Lights[86]	Alternate Horn Selection[87]/ Number Board Lights[88]	SMPH Report (Status Report)	Heavy Load (Disconnect-Standby-Total Shut Down)	Mute	Squealing Brakes/Flanges /Air Brakes (Cylinder Cocks/ Long Air Let-Off	Doppler (Start Up)	Dynamic Brakes
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Output 14	**Output 13**	**Output 12**	**Output 11**	**Output 10**	**Output 9**	**Output 8**	**Output 7**

- QSI has pre-assigned default features to each output but any feature can be assigned to any output in CV 53. In CV 53, the default setting for Output 13 is Number Board Lights. Therefore F11 controls Number Board Lights.
- You can specify that F11 control any of Outputs 7-12 and 14 in addition to or instead of Output 13.
- Assuming the default CV 53 settings (shown in the top row)[89], you can specify that F11 control the following features.

Bit 0 Output 7: Dynamic Brakes

"0" Dynamic Brakes are unaffected by F11.
"1" Dynamic Brakes are affected by F11.

Bit 1 Output 8: Doppler, Start Up

"0" Doppler shift in Forward/Reverse and Start up in Neutral are unaffected by F11.
"1" Doppler shift in Forward/Reverse and Start up in Neutral are affected by F11.

Bit 2 Output 9: Squealing Brakes and Air Brakes, Cylinder Cocks Arm or Long Air Let-off

"0" Squealing Brakes, Air Brakes in Forward/Reverse and Cylinder Cocks Arm, Long Air Let-off are unaffected by F11.
"1" Squealing Brakes, Air Brakes in Forward/Reverse and Cylinder Cocks Arm, Long Air Let-off are affected by F11.

85 Write bit operation is supported for CV 45.
86 Cab Lights are usually selected by default in Multiple Lights #3, which is the actual feature assigned to Output 14 (see CV 55.138). Depending on your model, different lights may be selected for Multiple Lights #3.
87 Alternate Horn is available only on selected models. Consult your Model's Operation Manual feature list.
88 Number Board Lights are usually selected by default in Multiple Lights #2, which is the actual feature assigned to Output 13 (see CV 55.137). Depending on your model, different lights may be selected for Multiple Lights #2.
89 Features that are different in the Neutral state are shown in parentheses

Bit 3 Output 10: Audio Mute**Error! Bookmark not defined.**

"0" Audio Mute is unaffected by F11.
"1" Audio Mute is affected by F11.

Bit 4 Output 11: Heavy Load, Disconnect-Standby-Total Shut Down

"0" Heavy Load in Forward/Reverse and Disconnect-Standby-Total Shut Down in Neutral are unaffected by F11.
"1" Heavy Load in Forward/Reverse and Disconnect-Standby-Total Shut Down in Neutral are affected by F11.

Note: Heavy Load has replaced the Cruise Control feature that was available on Lionel HO and early BLI locomotives.

Bit 5 Output 12: Speed Report, Status Report

"0" Speed Report in Forward/Reverse and Status Report in Neutral are unaffected by F11.
"1" Speed Report in Forward/Reverse and Status Report in Neutral are unaffected by F11.

Bit 6 Output 13: Number Board Lights

"0" Alternate Horn Selection or Number Board Lights are unaffected by F11.
"1" Alternate Horn Selection or Number Board Lights are affected by F11.

Bit 7 Output 14: Cab Lights

"0" Cab Lights are unaffected by F11.
"1" Cab Lights are affected by F11.

4.15 CV 46 Output Location for F12[90]

This CV specifies whether outputs 7 thru 14 are controlled by F12.

A '1' in a bit location specifies the output is controlled by F12, while a '0' specifies the output is not controlled by F12.

Default Value: **10000000 = 128**

CV 46: Output Location for F12 Register (with Factory Default Features)

Cab Lights[91]	Alternate Horn Selection[92]/ Number Board Lights[93]	SMPH Report (Status Report)	Heavy Load (Disconnect-Standby-Total Shut Down)	Mute	Squealing Brakes – Air Brakes (Brake Set)	Doppler (Start Up)	Dynamic Brakes
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Output 14	**Output 13**	**Output 12**	**Output 11**	**Output 10**	**Output 9**	**Output 8**	**Output 7**

- QSI has pre-assigned default features to each output but any feature can be assigned to any output in CV 53. In CV 53, the default setting for Output 14 is Cab Lights. Therefore F12 controls Cab Lights.
- You can specify that F12 control any of Outputs 7-13 in addition to or instead of Output 14.
- Assuming the default CV 53 settings (shown in the top row)[94], you can specify that F12 control the following features.

Bit 0 Output 7: Dynamic Brakes

"0" Dynamic Brakes are unaffected by F12.
"1" Dynamic Brakes are affected by F12.

Bit 1 Output 8: Doppler, Start Up

"0" Doppler shift in Forward/Reverse and Start up in Neutral are unaffected by F12.
"1" Doppler shift in Forward/Reverse and Start up in Neutral are affected by F12.

Bit 2 Output 9: Squealing Brakes and Air Brakes, Cylinder Cocks Arm or Long Air Let-off

"0" Squealing Brakes, Air Brakes in Forward/Reverse and Cylinder Cocks Arm, Long Air Let-off are unaffected by F12.
"1" Squealing Brakes, Air Brakes in Forward/Reverse and Cylinder Cocks Arm, Long Air Let-off are affected by F12.

90 Write bit operation is supported for CV 46.
91 Cab Lights are usually selected by default in Multiple Lights #3, which is the actual feature assigned to Output 14 (see CV 55.138). Depending on your model, different lights may be selected for Multiple Lights #3.
92 Alternate Horn is available only on selected models. Consult your Model's Operation Manual feature list.
93 Number Board Lights are usually selected by default in Multiple Lights #2, which is the actual feature assigned to Output 13 (see CV 55.137). Depending on your model, different lights may be selected for Multiple Lights #2.
94 Features that are different in the Neutral state are shown in parentheses

Bit 3 Output 10: Audio Mute

"0" Audio Mute is unaffected by F12.
"1" Audio Mute is affected by F12.

Bit 4 Output 11: Heavy Load, Disconnect-Standby-Total Shut Down

"0" Heavy Load in Forward/Reverse and Disconnect-Standby-Total Shut Down in Neutral are unaffected by F12.
"1" Heavy Load in Forward/Reverse and Disconnect-Standby-Total Shut Down in Neutral are affected by F12.

Note: Heavy Load has replaced the Cruise Control feature that was available on Lionel HO and early BLI locomotives.

Bit 5 Output 12: Speed Report, Status Report

"0" Speed Report in Forward/Reverse and Status Report in Neutral are unaffected by F12.
"1" Speed Report in Forward/Reverse and Status Report in Neutral are unaffected by F12.

Bit 6 Output 13: Number Board Lights

"0" Horn Selection or Number Board Lights are unaffected by F12.
"1" Horn Selection or Number Board Lights are affected by F12.

Bit 7 Output 14: Cab Lights

"0" Cab Lights are unaffected by F12.
"1" Cab Lights are affected by F12.

5 CV's 49-64: QSI Unique CV's

5.1 Overview

Many of the available CV's have been reserved by the NMRA to provide standardized and compatible operation by all manufacturers with each other's products.

These standard CV's relate to operations that are common to all DCC products such as ID numbers, speed steps, and acceleration and deceleration rates.

Many model railroad products today, and a much larger number in the future, require manufacturer unique CV's to configure their product's special features. The command structure and protocols for changing and retrieving manufacturer unique CV values are standardized through the NMRA, but the individual manufacturers specify the meaning of the CV values.

The NMRA has provided a number of CV's for manufacturers to use in configuring their own products: CV's 49 through 64, and CV's 112-128.

Instead of filling up the available manufacturer unique CV's in a linear or chronological order, QSI uses an indexing system which organizes these CV's in a meaningful way.

Two of the available manufacturer unique CV's are used as indices to expand some of the remaining CV's into 256 register one-dimensional tables, or into 256x256 register two-dimensional tables.

CV 49 is the Primary Index (PI), and is used for accessing up to 256 registers of a one-dimensional table.

Primary Index CV 49	
0	CV X Register 0
1	CV X Register 1
2	CV X Register 2
3	CV X Register 3
: **:**	CV X Register n
255	CV X Register 255

CV 52 is an example of one of the CV's implemented as a one-dimensional table.

CV 50 is the Secondary Index (SI), and is used together with the Primary Index for accessing up to 256x256 registers of a two-dimensional table.

Primary Index CV 49	**Secondary Index CV 50**					
	0	1	2	3	**.. ..**	255
0	CV X Register 0,0	CV X Register 0,1	CV X Register 0,2	CV X Register 0,3	CV X Register 0,m	CV X Register 0,255
1	CV X Register 1,0	CV X Register 1,1	CV X Register 1,2	CV X Register 1,3	CV X Register 1,m	CV X Register 1,255
2	CV X Register 2,0	CV X Register 2,1	CV X Register 2,2	CV X Register 2,3	CV X Register 2,m	CV X Register 2,255
3	CV X Register 3,0	CV X Register 3,1	CV X Register 3,2	CV X Register 3,3	CV X Register 3,m	CV X Register 3,255

: **:**	CV X Register n,0	CV X Register n,1	CV X Register n,2	CV X Register n,3	CV X Register n,m	CV X Register n,255
255	CV X Register 255,0	CV X Register 255,1	CV X Register 255,2	CV X Register 255,3	CV X Register 255,m	CV X Register 255,255

CV 53 is an example of one of the CV's implemented as a two-dimensional table.

5.2 CV 49 QSI Primary Index

Use CV 49 to specify the Primary Index for a CV that is implemented as a one-dimensional or two-dimensional array.

Default Value: **0**

CV 49: Primary Index Register (PI)

Bit 7 (MSB)	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0 (LSB)
P7	**P6**	**P5**	**P4**	**P3**	**P2**	**P1**	**P0**

- CV 49 is used as an index into a table of up to 256 related values.

Primary Index	Table of Values
0	Value[0]
1	Value[1]
2	Value[2]
3	Value[3]
…	…

- For example, CV 49 is used as an index for CV 52 which contains the volume levels for up to 256 Individual Sounds.

Primary Index	Table of Volume Levels
0	Volume Level for Sound[0]
1	Volume Level for Sound[1]
2	Volume Level for Sound[2]
3	Volume Level for Sound[3]
…	…

- In this document the terms CV 49 and Primary Index mean the same thing. PI is the abbreviation for Primary Index.
- We use a shorthand notation to simplify description of a CV that is composed of a one-dimensional table of values. The elements of the table are referred to as CV NN.PI, where NN is the CV number, and PI is the Primary Index. For example, Individual Sound Volume 5 is written CV 52.5. During verbal acknowledgement or during CV Numeric Verbal Readout (CV 64) from the locomotive, it is spoken out as “CV five two point five”.

5.3 CV 50 QSI Secondary Index

Use CV 50 to specify the Secondary Index for a CV that is implemented as a two-dimensional array.

Default Value: **0**

CV 50: Secondary Index Register (SI)

Bit 7 (MSB)	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0 (LSB)
S7	**S6**	**S5**	**S4**	**S3**	**S2**	**S1**	**S0**

- CV 50 is used along with CV 49 as an index into a two-dimensional table of up to 256x256 related values. CV 49 is the row index and CV 50 is the column index.

	Secondary Index				
Primary Index	**0**	**1**	**2**	**3**	…
0	Value[0,0]	Value[0,1]	Value[0,2]	Value[0,3]	…
1	Value[1,0]	Value[1,1]	Value[1,2]	Value[1,3]	…
2	Value[2,0]	Value[2,1]	Value[2,2]	Value[2,3]	…
3	Value[3,0]	Value[3,1]	Value[3,2]	Value[3,3]	…
…	…	…	…	…	…

- For example, CV 53 uses CV 49 as a row index (1…14) and CV 50 as a column index (0...1) to assign different QSI Features to each of fourteen outputs for two states: Forward/Reverse, and NFF/NFR.

	Secondary Index	
Primary Index	**0**	**1**
1	Feature Assigned to Output 1 in FWD/REV	Feature Assigned to Output 1 in NFF/NFR
2	Feature Assigned to Output 2 in FWD/REV	Feature Assigned to Output 2 in NFF/NFR
3	Feature Assigned to Output 3 in FWD/REV	Feature Assigned to Output 3 in NFF/NFR
…	…	…
14	Feature Assigned to Output 14 in FWD/REV	Feature Assigned to Output 14 in NFF/NFR

- In this document the terms CV 50 and Secondary Index mean the same thing. SI is the abbreviation for Secondary Index.
- We use a shorthand notation to simplify description of a CV that is composed of a two-dimensional table of values. The elements of the table are referred to as CV NN.PI.SI, where NN is the CV number, PI is the Primary Index, and SI is the Secondary Index. For example, the CV for output 4 in neutral is written CV 53.4.1. During verbal acknowledgement or during CV Numeric Verbal Readout (CV 64) from the locomotive, it is spoken out as “CV five three point four point one”.

5.4 CV 51.PI QSI System Sound Control

Use CV 51 to control your Quantum locomotive's System Volume, Mute Volume and Special Sound Effects

CV51 is implemented as a one-dimensional array, with CV 49 used as an index to these CV 51 registers.

5.4.1 CV 51.0 Operations Mode System Volume (PI = 0)

Use CV 51.0 to change the System Volume.

Default Value: **127**

CV 51.0: Ops Mode System Volume Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	**V6**	**V5**	**V4**	**V3**	**V2**	**V1**	**V0**

- Set CV 49 to "0" to specify the Primary Index for **Operations Mode System Volume**.
- The System Volume can be set to any value between 0 (no sound) and 127 (100%). The upper bit is reserved and should be 0. The default Operations Mode Volume is 127 **(100%)**. A "0" in this CV will reduce all sound effects to zero volume.
- The Operations Mode System Volume is the overall sound volume when the locomotive is in normal operation on the main (Operations Mode). When you change the Operations Mode System Volume on the main, you will immediately hear the change in volume.
- All sound is turned off in Service Mode because of the limited power usually available for the programming track. You can program the System Volume in Service Mode, but you won't hear the change in volume until you enter Operations Mode.

Note: The system volume in this CV is the same system volume used during conventional Analog operation. Changing this CV changes the system volume in Analog DC, and changing the system volume in Analog DC changes the value of this CV.

Example: Set the Operations Mode System volume to 64 (50% of max).
1. Set CV 49 to 0. 2. Set CV 51 to 64.

5.4.2 CV 51.1 Operations Mode Mute Volume (PI = 1)

Use CV 51.0 to change the Mute Volume.. Mute is one of the Quantum features that can be turned on and off by a Function Key. When Mute is “On”, the overall volume reduces to the volume set by CV 51.1.

Default Value: **0**

CV 51.1: Ops Mode Mute Volume Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	**0**	**V5**	**V4**	**V3**	**V2**	**V1**	**V0**

- Set CV 49 to “1” to specify the Primary Index for **Operations Mode Mute Volume**.
- The Mute Volume can be set to any value between 0 (no sound) and 63 (50%). If the Mute Volume is set over 50% of the System Volume set in CV 51.0, the applied Mute Volume will be 50% of the System Volume setting. The upper bit is reserved and should be 0. A “0” in this CV will mute all sound effects to zero volume.
- The default Mute Volume is 0 **(0%)**.
- The Mute Volume applies when the locomotive is in normal operation on the main (Operations Mode). When you change the Mute Volume on the main and “Mute” has been turned “On” by its assigned Function Key, you will immediately hear the change in volume.
- If you program the Mute Volume in Service Mode, you won’t hear the change in Mute volume until you enter Operations Mode and activate the Mute feature.

Example: Set the Operations Mode Mute Volume to 32 (25% of max).
1) Set CV 49 to 1. 2) Set CV 51 to 32.

5.4.3 CV 51.2 Special Sound Effects Enable[95] (PI = 2)

Use CV 51.2 to enable/disable special sound effects.

Default Value: **Depends on Locomotive**

CV 51.2: Special Sound Effects Enable Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved for future use	Reserved for future use	Cylinder Cocks Armed after 25 seconds in NFF/NFR	Cylinder Cocks Armed on Startup	Heavy Load On/Off Feedback	Alternate Horn Selection Feedback	Coded Horn for Gas Turbine Start Up[96]	Horn Triggered Doppler

- Write 2 to CV 49 to specify the Primary Index for **Special Sound Effects Enable.**
- Set data in Bit 0 as follows:

  "0" = Horn triggered Doppler effect is disabled.
  "1" = Horn triggered Doppler effect is enabled. (Default)

  If Horn Triggered Doppler is enabled, you can obtain a Doppler effect by first blowing the Horn for a least one second. Any time thereafter, briefly interrupt the horn signal by releasing the function key and reapplying to produce the Doppler effect.

- Set data in Bit 1 as follows:

  "0" = Coded Horn triggered Gas Turbine Start Up is disabled.
  "1" = Coded Horn triggered Gas Turbine Start Up is enabled. (Default)

  If Coded Horn triggered Gas Turbine Start Up is enabled, then 4 short horn blasts in neutral will cause the Gas Turbine decoder to transition from Diesel to Turbine operation or from Turbine to Diesel operation.

- Set data in Bit 2 as follows:

  "0" = Alternate Horn Selection Feedback is disabled.
  "1" = Alternate Horn Selection Feedback is enabled. (Default)

  If Alternate Horn Selection Feedback is enabled, then the newly selected Horn sounds a short hoot when it is selected. Only certain models have an Alternate Horn.

- Set data in Bit 3 as follows:

  "0" = Heavy Load On/Off Feedback is disabled.
  "1" = Heavy Load On/Off Feedback is enabled. (Default)

  If Heavy Load On/Off Feedback is enabled, a single horn hoot is played when Heavy Load is turned on. When Heavy Load is turned off, two horn hoots are played.

- Set data in Bit 4 as follows:

  "0" = Cylinder Cocks are not automatically armed as a result of a Startup (F6) operation.
  "1" = Cylinder Cocks are automatically armed as a result of a Startup (F6) operation. (Default)

  If this bit is "1" and a Startup (F6) operation occurs, Cylinder Cocks sounds play when the locomotive starts moving in FWD/REV. The Cylinder Cocks sounds automatically terminate after 16 repetitions or when the locomotive reaches a speed greater than 12 smph.

- Set data in Bit 5 as follows:

95 Write bit operation is supported for Special Sound Effects Enable.
96 See Gas Turbine Operation in Appendix II for further explanation of this feature.

"0" = Cylinder Cocks are not automatically armed after 25 seconds in NFF/NFR.
"1" = Cylinder Cocks are automatically armed after 25 seconds in NFF/NFR. (Default)

If this bit is "1" and the locomotive remains in neutral for at least 25 seconds, Cylinder Cocks sounds play when the locomotive starts moving in FWD/REV. The Cylinder Cocks sounds automatically terminate after 16 repetitions or when the locomotive reaches a speed greater than 12 smph.

- All other bits are reserved. Any data entered in these bits is ignored.

Example: Set Special Sound Effects according to Feature Table below.
Set CV 49 to 2. Set CV 51 to value indicated for the combination of features you want.

Cylinder Cocks Armed after 25 seconds in NFF/NFR	Cylinder Cocks Armed on Startup	Heavy Load On/Off Feedback	Std/Alt Horn Select Feedback	Coded Horn for Gas Turbine Start Up	Horn Triggered Doppler	Decimal Value	Binary Value	Hex Value
						0	00000000	00
					X	1	00000001	01
				X		2	00000010	02
				X	X	3	00000011	03
			X			4	00000100	04
			X		X	5	00000101	05
			X	X		6	00000110	06
			X	X	X	7	00000111	07
		X				8	00001000	08
		X			X	9	00001001	09
		X		X		10	00001010	0A
		X		X	X	11	00001011	0B
		X	X			12	00001100	0C
		X	X		X	13	00001101	0D
		X	X	X		14	00001110	0E
		X	X	X	X	15	00001111	0F
	X					16	00010000	10
	X				X	17	00010001	11
	X			X		18	00010010	12
	X			X	X	19	00010011	13
	X		X			20	00010100	14
	X		X		X	21	00010101	15
	X		X	X		22	00010110	16
	X		X	X	X	23	00010111	17
	X	X				24	00011000	18
	X	X			X	25	00011001	19
	X	X		X		26	00011010	1A
	X	X		X	X	27	00011011	1B
	X	X	X			28	00011100	1C
	X	X	X		X	29	00011101	1D
	X	X	X	X		30	00011110	1E
	X	X	X	X	X	31	00011111	1F
X						32	00100000	20
X					X	33	00100001	21
X				X		34	00100010	22
X				X	X	35	00100011	23
X			X			36	00100100	24
X			X		X	37	00100101	25
X			X	X		38	00100110	26
X			X	X	X	39	00100111	27
X		X				40	00101000	28
X		X			X	41	00101001	29
X		X		X		42	00101010	2A
X		X		X	X	43	00101011	2B
X		X	X			44	00101100	2C
X		X	X		X	45	00101101	2D
X		X	X	X		46	00101110	2E
X		X	X	X	X	47	00101111	2F
X	X					48	00110000	30
X	X				X	49	00110001	31
X	X			X		50	00110010	32
X	X			X	X	51	00110011	33
X	X		X			52	00110100	34
X	X		X		X	53	00110101	35
X	X		X	X		54	00110110	36
X	X		X	X	X	55	00110111	37
X	X	X				56	00111000	38
X	X	X			X	57	00111001	39
X	X	X		X		58	00111010	3A
X	X	X		X	X	59	00111011	3B
X	X	X	X			60	00111100	3C
X	X	X	X		X	61	00111101	3D
X	X	X	X	X		62	00111110	3E
X	X	X	X	X	X	63	00111111	3F

5.4.4 CV 51.5 Automatic Mute Timeout Value (PI = 5)

Use this CV to specify the number of seconds of "idle time" after which the locomotive automatically mutes its sounds.

Default Value: **0**

CV 51.5: Automatic Mute Timeout Value Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- Each unit represents 10 seconds. The maximum value is 255, which represents 2550 seconds or 42 minutes and 30 seconds.
- If the number of specified seconds of idle time is exceeded, the locomotive's sounds are automatically reduced to the Mute Volume specified in CV51.1. If the locomotive's sounds are already muted via the Mute function, the locomotive's sounds will not change in volume.
- If the value of this CV is “0”, this timeout is disabled. Sounds are not automatically muted.
- Idle time is defined as the period of time during which the locomotive is in neutral and receives only Speed packets with speed step "0".
- If the locomotive receives a Speed packet with speed step > 0, or any non speed packet such as a Function packet or Configuration Variable Access packet, then the idle time is immediately reset and the sounds return to their previous volume.
- Idle time also includes the case where the locomotive receives no valid packets addressed specifically to its Primary, Extended, or Consist address. This overlaps with the condition which triggers the CV11 Packet Timeout, but CV51.5 is independent of CV11 and vice versa. Either or both timeouts may be enabled and do not interfere with each other.

  Example 1: Suppose CV11 = "10" and CV51.5 = "6". Suppose the locomotive enters neutral (speed step 0) and the locomotive receives no packets other than Speed "0" packets. After 60 seconds of this, the locomotive's sounds are reduced to the CV51.1 Mute Volume.

  Example 2: Suppose CV11 = "10" and CV51.5 = "6". The locomotive's speed corresponds to the last received Speed packet specifying speed step "30". The locomotive does not receive any valid packets addressed to one of its addresses. After 10 seconds of this the CV11 Packet Timeout Value is exceeded and the locomotive automatically slows to a stop and enters neutral, but the locomotive's sounds do not change in volume. After the locomotive comes to a stop and after 60 additional seconds of receiving no valid packets addressed to one of its addresses, the locomotive's sounds are reduced to the CV51.1 Mute Volume.

Example: Set the Automatic Mute Timeout Value to 10 (100 seconds).
3) Set CV 49 to 5. 4) Set CV 51 to 10.

5.5 CV 52.PI QSI Individual Sound Volume Control

Use CV 52 to specify volume levels for individual Quantum sounds.

CV 52.PI: Individual Sound Volume Registers

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	**0**	**0**	**0**	**V3**	**V2**	**V1**	**V0**

- CV 52 is implemented as a one-dimensional table of up to 256 Individual Sound Volume registers, with CV 49 used as an index to these registers.

Primary Index	Table of Volume Levels
0	Volume Level for Sound[0]
1	Volume Level for Sound[1]
2	Volume Level for Sound[2]
3	Volume Level for Sound[3]
…	…

- To change the volume level of an individual sound, do the following:
  1) Set CV 49 to the identifier for the individual sound (see table next page).
  2) Set data in Bits 0-3 of CV 52 as follows:

     "0" = No sound
     "1 – 15" = Sets volume level from the lowest level at "1" to the highest level at "15"

- 4 bits of volume level are used, providing 16 volume levels. The volume levels correspond to 2db increments.
- All other bits are reserved. Data in bits 4-7 are not used. Any data entered in these bits will be ignored.

Example: Set the bell volume to the 6th volume level and then set the Horn/Whistle volume to 10th level (i.e. set CV 52.8 to 6 followed by setting CV 52.0 to 11)
1. Set CV 49 to 8 to select the Bell sound. 2. Set CV 52 to 6 to select the 6th volume level for the Bell. 3. Set CV 49 to 0 to select the Horn/Whistle sound. 4. Set CV 52 to 10 to select the 10th volume level for the Horn/Whistle.

Example: For dual Air Pump Steam Locomotives, turn the volume off on one pump to create single pump action.
1. Set CV 49 to 17 to select the second pump sound. 2. CV 52 to zero to select no volume.

5.5.1 Individual Sound Identifiers

Primary Index (CV 49 value)	Sound	Typical Default Levels[97]
0	**Horn/Whistle[98]**	11
8	**Bell**	11
10	**Chuff/Diesel Motor/Traction Motor[99]**	11
11	**Chuff 2 (Articulated Steam Locomotives Only)**	11
13	**Gas Turbine Whoosh**	11
14	**Turbo**	11
15	**Cylinder Cocks or Gas Turbine Whine**	11
16	**Air Pump 1**	11
17	**Air Pump 2 (Steam Locomotives Only)**	11
19	**Steam Blower Hiss/ Fans[100]**	8/11
21	**Long Air Let-off**	11
22	**Short Air Let-off**	11
24	**Squealing Brakes**	11
26	**Steam Dynamo/Diesel Generator**	11
28	**Dynamic Brakes Fans**	11
29	**Boiler Pop-off**	11
30	**Blow down**	11
31	**Injector**	11
34	**Coupler Sounds**	11
37	**Air Brakes**	11
40	**Alternate Horn Volume**	11
46	**User Sound Effect Volume**	11

97 Default levels for individual sounds may be set to different levels at the factory then are shown here depending on the acoustic nature of each locomotive. Check the value of your default settings in your individual locomotive's instruction manual.

98 Whistle in Steam Locomotives; Horn in Diesel and Electric Locomotives.

99 Chuff in Steam Locomotives; Diesel Motor in Diesel Locomotives; Traction Motor in Electric Locomotives.

100 Steam Blower in Steam Locomotives; Cooling Fans in Diesel and Electric Locomotives.

5.6 CV 53.PI.SI Output Feature Assignment

Use CV 53 to assign QSI features to the 14 decoder outputs.

CV 53.PI.SI: Output Feature Assignment Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- CV 53 is implemented as a two-dimensional table of 14x2 registers, with CV 49 used as a row index to these registers, and CV 50 used as a column index.

	Secondary Index (CV 50)	
Primary Index (CV 49)	**0**	**1**
1	Feature Assigned to Output 1 in FWD/REV	Feature Assigned to Output 1 in NFF/NFR
2	Feature Assigned to Output 2 in FWD/REV	Feature Assigned to Output 2 in NFF/NFR
3	Feature Assigned to Output 3 in FWD/REV	Feature Assigned to Output 3 in NFF/NFR
4	Feature Assigned to Output 4 in FWD/REV	Feature Assigned to Output 4 in NFF/NFR
5	Feature Assigned to Output 5 in FWD/REV	Feature Assigned to Output 5 in NFF/NFR
6	Feature Assigned to Output 6 in FWD/REV	Feature Assigned to Output 6 in NFF/NFR
7	Feature Assigned to Output 7 in FWD/REV	Feature Assigned to Output 7 in NFF/NFR
8	Feature Assigned to Output 8 in FWD/REV	Feature Assigned to Output 8 in NFF/NFR
9	Feature Assigned to Output 9 in FWD/REV	Feature Assigned to Output 9 in NFF/NFR
10	Feature Assigned to Output 10 in FWD/REV	Feature Assigned to Output 10 in NFF/NFR
11	Feature Assigned to Output 11 in FWD/REV	Feature Assigned to Output 11 in NFF/NFR
12	Feature Assigned to Output 12 in FWD/REV	Feature Assigned to Output 12 in NFF/NFR
13	Feature Assigned to Output 13 in FWD/REV	Feature Assigned to Output 13 in NFF/NFR
14	Feature Assigned to Output 14 in FWD/REV	Feature Assigned to Output 14 in NFF/NFR

- To change an output assignment, do the following:
    1) Set CV 49 to the decoder Output Number (1…14).
    2) Set CV 50 to the Locomotive State (0 for Forward/Reverse, 1 for Neutral (NFF/NFR).
    3) Set CV 53 to the QSI Feature Identification Number (see table next page)
- Certain features can only be assigned to an output for a specific state.
- Never assign the same feature to two or more outputs; it is unclear what the effect will be since both outputs may have different states. For instance, if you assign the Blower Hiss to Output 5 and to Output 7, and Output 5 is off but Output 7 is on, would Blower Hiss be on or off?

Example: Set Long Air Let-Off to Output 5 to operate in Forward and Reverse and set Short Air Let-Off to Output 5 to operate in Neutral (i.e. set CV 53.5.0 to 9 and set CV 53.5.1 to 10).

1) Set Primary Index CV 49 to “5” to select output 5.
2) Set Secondary Index CV 50 to “0” to select Forward/Reverse.
3) Set CV 53 to “9” (00000101) which is Long Air Let-Off Feature ID Number.
4) Set Secondary Index CV 50 to “1” to select Neutral. (CV 49 is already set to output 5.)
5) Set CV 53 to “10” (00001010) for Short Air Let-Off.

Now the Function key mapped to output 5 will produce a Short Air-Let-Off when the locomotive is in Neutral, and a Long Air Let-Off when the locomotive is moving in Forward and Reverse.

5.6.1 QSI Feature Identification Numbersused with CV 53

The following table lists the QSI Features that may be assigned to function key outputs.

The third column shows the directional states (All, Forward/Reverse, Neutral) for which the feature may be assigned to an output. Some features, like Blower Hiss or Mute, apply to all states; some features, like Doppler and Squealing Brakes, only apply to a moving locomotive; some features, like Pop-off or Blow-Down, only apply to Neutral. The Quantum System allows you to assign, say, Squealing Brakes to Output 7 in Neutral but when the F5 Key is pressed to activate this feature in Neutral, it will produce no effect.

Feature	Feature ID	Allowed Directional States	Comments
Air Brakes	**176**	FWD/REV	See section "1.13 Air Brakes (F7 in Forward or Reverse)".
Alternate Horn Selection	**2**	All	This selects between the primary warning device be it either Horn or Whistle and an alternate Horn. Each time you make a selection, you hear a short hoot that identifies the Horn or Whistle selected. To disable feedback, see CV 51.2.
Arm Cylinder Cocks	**6**	NFF/NFR	Explicitly arms Cylinder Cocks. If Cylinder Cocks are armed, Cylinder Cocks sounds play when the locomotive begins moving in FWD/REV. The Cylinder Cocks sounds automatically terminate after 16 repetitions or when the locomotive reaches a speed greater than 12 smph. See CV 51.2.
Automatic Ditch Lights	**84**	All	When Automatic Ditch Lights is activated, the Ditch Lights intensity changes automatically in response to changes to the locomotive's directional state. See CV 55.84.x.
Automatic Front Cab Lights	**116**	All	When Automatic Front Cab Lights is activated, the Front Cab Lights intensity changes automatically in response to changes to the locomotive's directional state. See CV 55.116.x.
Automatic Front Marker Lights	**104**	All	When Automatic Front Marker Lights are activated, the Front Marker Light intensity changes automatically in response to changes to the locomotive's directional state. See CV 55.104.x.
Automatic Front Number Board Lights	**100**	All	When Automatic Front Number Board Lights is activated, Front Number Board Light intensity changes automatically in response to changes to the locomotive's directional state. See CV 55.100.x.
Automatic Headlight	**70**	All	If Automatic Headlight is activated, the Headlight intensity changes automatically in response to changes to the locomotive's directional state. See CV 55.70.x.
Automatic Mars Light	**76**	All	If Automatic Mars Light is activated, the Mars Light intensity changes automatically in response to changes to the locomotive's directional state. See CV 55.76.x.
Automatic Rear Cab Lights	**118**	All	When Automatic Rear Cab Lights is activated, Rear Cab Lights turn off in Forward/Reverse after 15 seconds and turn on in Neutral after 10

			seconds. See CV 55.118.x.
Automatic Rear Ditch Lights	**88**	All	When Automatic Rear Ditch Lights is activated, the Rear Ditch Lights intensity changes automatically in response to changes to the locomotive's directional state. See CV 55.88.x.
Automatic Rear Marker Lights	**106**	All	When Automatic Rear Marker Lights is activated, the Rear Marker Light intensity changes automatically in response to changes to the locomotive's directional state. See CV 55.108.x.
Automatic Rear Mars Light	**80**	All	If Automatic Rear Mars Light is activated, the Rear Mars Light intensity changes automatically in response to changes to the locomotive's directional state. See CV 55.80.x.
Automatic Rear Number Board Lights	**102**	All	When Automatic Rear Number Board Lights is activated, Rear Number Board Light intensity changes automatically in response to changes to locomotive's directional state. See CV 55.102.x.
Automatic Reverse Light	**73**	All	When Automatic Reverse Light is activated, the Reverse Light intensity changes automatically in response to changes in the locomotive's directional state. See CV 55.73.x.
Bell	**3**	All	When on, the bell rings continuously. Some bells have both start up and shut down sounds. See section "1.7 Horn and Bell Buttons (F2 Key and F1 Key)". See also CV 55.3.x.
Blow down	**13**	NFF/NFR	Blow Down produces a sound sequence of venting water, steam and residue that collects at the bottom of the boiler. The length of the Blow Down sequence is random. Blow Down sounds are produced automatically in Neutral at random intervals so there is no need to assign this feature to a function key output unless you really want to.
Blower Hiss	**8**	All	See section "1.9 Steam Blower Hiss and Cooling Fans (F4 Key)".
Cooling Vents and Fans	**8**	All	See section "1.9 Steam Blower Hiss and Cooling Fans (F4 Key)".
Coupler	**211**	All	See section "1.8 Coupler and Coupler Crash Sounds (F3 Key)".
GasTurbine/Diesel Transition	**24**	NFF/NFR	Selects between Diesel mode and Turbine mode for the UP Gas Turbine Locomotive.
Dim Ditch Lights	**86**	All	Explicitly switches the Ditch Lights from Bright to be Dim. See CV 55.84.x.
Dim Headlight	**72**	All	Explicitly switches the Headlight from Bright to Dim. See CV 55.70.x.
Dim Mars Light	**78**	All	Explicitly switches the Mars Light from Bright to Dim. See CV 55.76.x.
Dim Rear Ditch Lights	**90**	All	Explicitly switches the Rear Ditch Lights from Bright to be Dim. See CV 55.88.x.
Dim Rear Mars Light	**82**	All	Explicitly switches the Rear Mars Light from Bright to Dim. See CV 55.80.x.
Dim Reverse Light	**75**	All	Explicitly switches the Reverse light from Bright to Dim. See CV 55.73.x.
Disconnect/Standby/Total Shut Down	**145**	NFF/NFR	See section "1.17 Three Stages of Shut Down: Disconnect, Standby and Total Shut Down (F9 in Neutral)".
Ditch Lights	**85**	All	Explicitly turns the Ditch Lights On or Off. See CV

			55.84.x.
Doppler Shift	**65**	FWD/REV	See section “1.11 Doppler Shift (F6 in Forward and Reverse)”.
Dynamic Brakes	**5**	FDW/REV and Disconnect	See section “1.10 Dynamic Brakes (F5 Key)”.
Flanges/ Squealing Brakes	**215**	FWD/REV	See section “1.12 Squealing Brakes and Flanges (F7 in Forward or Reverse)”.
Flanges/ Squealing Brakes + Air Brakes	**216**	FWD/REV	This feature is a combination of Flanges/Squealing Brakes, 215, and Air Brakes, 176. If assigned to a function key and pressed when Air Brakes would not normally be functional (i.e. throttle at some non-zero setting), squealing brakes would still be heard.
Front Cab Lights	**117**	All	Explicitly turns the Front Cab Lights On or Off. See CV 55.116.x.
Front Marker Lights	**105**	All	Explicitly turns the Front Marker Lights On or Off. See CV 55.104.x.
Front Number Board Lights	**101**	All	Explicitly turns the Front Number Board Lights On or Off. See CV 55.100.x.
Grade Crossing	**154**	FWD/REV	Plays a grade crossing scenario consisting of four horn blasts: two long blasts, one short blast, and one long blast.
Headlight	**71**	All	Explicitly turns the Headlight On or Off. See CV 55.70.x.
Heavy Load	**179**	All	See section “1.15 Heavy Load (F9 in Forward or Reverse”.
Horn	**1**	All	See section “1.7 Horn and Bell Buttons (F2 Key and F1 Key)”.
Injector	**14**	NFF/NFR	When triggered, Injector produces a sound sequence of water being injected into the boiler. This can happen in any directional state but it is more obvious in Neutral. The length of the Injector sequence is random. Injector sounds are produced automatically in Neutral at random intervals so there is no need to assign this feature to a function key output unless you really want to.
Long Air Let-off	**9**	All	When triggered, Long Air Let-off produces an air release sound of about 1.5 seconds. Use a Long Air Let-off to simulate operating some steam appliances like power reverse or applying the brakes in Neutral on any locomotive.
Mars Light	**77**	All	Explicitly turn the Mars Light On or Off. See CV 55.76.x.
Multiple Automatic Lights #1	**136**	All	The Multiple Automatic Lights #1 feature allows you to activate more than one automatic light feature with a single function key. See CV 55.136.x.
Multiple Automatic Lights #2	**137**	All	The Multiple Automatic Lights #2 feature allows you to activate more than one automatic light feature with a single function key. See CV 55.137.x
Multiple Automatic Lights #3	**138**	All	The Multiple Automatic Lights #3 feature allows you to activate more than one automatic light feature with a single function key. See CV

			55.138.x.
Mute	**64**	All	See section “1.14 Audio Mute (F8 Key)”.
None	**0**	All	If this feature is assigned to a function key output, pressing the function key does nothing.
Overhead Beacon Light	**92**	All	Explicitly turns the Overhead Beacon Light On or Off. See CV 55.92.x.
Pop-off	**12**	NFF/NFR	When triggered, Pop Off produces a sound sequence of steam being ejected from the boiler. This can happen in any directional state but it is more obvious in Neutral. The length of the Pop Off sequence is random. Pop Off sounds are produced automatically in Neutral at random intervals so there is no need to assign this feature to a function key output unless you really want to.
Rear Cab Lights	**119**	All	Explicitly turns the Rear Number Board Lights On or Off. See CV 55.118.x.
Rear Ditch Lights	**89**	All	Explicitly turns the Rear Ditch Lights On or Off. See CV 55.88.x.
Rear Marker Lights	**107**	All	Explicitly turns the Rear Marker Lights On or Off. See CV 55.106.x.
Rear Mars Light	**81**	All	Explicitly turn the Rear Mars Light On or Off. See CV 55.80.x.
Rear Number Board Lights	**103**	All	Explicitly turns the Rear Number Board Lights On or Off. See CV 55.102.x.
Rear Overhead Beacon Light	**96**	All	Explicitly turns the Rear Overhead Beacon Light On or Off. See CV 55.96.x.
Reverse Light	**74**	All	Explicitly turns the Reverse light On or Off. See CV 55.73.x.
Short Air Let-off	**10**	All	When triggered, Short Air Let-off produces an air release sound of about 1 second. Use a Short Air Let-off to simulate operating some locomotive appliances or as a place holder feature for unused function keys.
Start Up	**144**	NFF/NFR	See section “1.18 Start Up (F6 in Neutral)”.
Status Report	**178**	All	See section “1.16 Status Report (F10)”.
Step Lights	**113**	All	Explicitly turns the Front Step Lights On or Off. See CV 55.112.x.
Strobe Ditch Lights	**87**	All	Explicitly turns on or off Ditch Lights strobe. See CV 55.84.x.
Strobe Mars Light	**79**	All	Explicitly turns on or off Mars Light strobe. See CV 55.76.x.
Strobe Rear Ditch Lights	**91**	All	Explicitly turns on or off Rear Ditch Lights strobe. See CV 55.88.x.
Strobe Rear Mars Light	**83**	All	Explicitly turns on or off Rear Mars Light strobe. See CV 55.80.x.
User Looped Sound Effect	**26**	All	Turn on/off a User Recorded Sound Effect. See Q2Upgrade User Manual for further information.
User Sound Effect	**25**	All	Trigger the single playing of a User Recorded Sound Effect. See Q2Upgrade User Manual for further information.
Whistle	**1**	All	See section “1.7 Horn and Bell Buttons (F2 Key and F1 Key)”.

Note: Do not confuse the above table with the Individual Sound Identifiers Table shown in CV 52. The above table lists ID’s of Features while CV 52 table lists ID’s of Individual Sounds.

5.6.2 CV 53 Factory Default Settings

		Secondary Index (SI) (CV 50 Value)	
		0	1
Primary Index (PI) (CV 49 Value)		**Forward/Reverse only**	**Neutral only**
1	**Output 1**	Multiple Automatic Lights #1 (136)	Multiple Automatic Lights #1 (136)
2	**Output 2**	Multiple Automatic Lights #1 (136)	Multiple Automatic Lights #1 (136)
3	**Output 3**	Bell (3)	Bell (3)
4	**Output 4**	Horn/Whistle (1)	Horn/Whistle (1)
5	**Output 5**	Coupler (211)	Coupler (211)
6	**Output 6**	Blower Hiss/Fans (8)	Blower Hiss/Fans (8)
7	**Output 7**	Dynamic Brakes (5)	Dynamic Brakes (5)
8	**Output 8**	Doppler Shift (65)	Start Up (144)
9	**Output 9**	Squealing Brakes + Air Brakes (216)	Long Air Let-off (9) or Arm Cylinder Cocks (6)
10	**Output 10**	Mute (64)	Mute (64)
11	**Output 11**	Heavy Load (179)	Disconnect/Standby/ Shut Down (145)
12	**Output 12**	Status Report (178)	Status Report (178)
13	**Output 13**	Alternate Horn Selection (2) Multiple Automatic Lights #2 (137)	Alternate Horn Selection (2) Multiple Automatic Lights #2 (137)
14	**Output 14**	Multiple Automatic Lights #3 (138)	Multiple Automatic Lights #3 (138)

5.7 CV 55.PI.SI QSI Feature Configuration

Use CV 55 to configure the behavior of Quantum features.

CV 55 is implemented as a two-dimensional array of registers. with both CV 49 and CV 50 used to access these registers. The CV 49 Primary Index corresponds to QSI feature ID numbers.

5.7.1 CV 55.3.SI Bell

5.7.1.1 CV 55.3.0 Maximum Bell Index

This read-only CV contains the number of prototypical bell sounds available in your Quantum Decoder.

Default Value: **Depends on Locomotive**

CV 55.3.0: Maximum Bell Index

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- In Service Mode, to determine the number of bells available:
    1) Set CV 49 to 3.
    2) Set CV 50 to 0.
    3) Then read back CV 55.
- In Ops Mode, to determine the number of bells available:
    1) Set CV 49 to 3.
    2) Set CV 50 to 0.
    3) Then set CV 64 to 55 to hear a verbal response.

5.7.1.2 CV 55.3.1 Bell Select

Your Quantum Decoder may have more than one type of prototypical bell sound. Use CV 55.3.1 to choose from the available bell sounds.

Default Value: **1**[101]

CV 55.3.1: Bell Select

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- Use CV 55.3.0 to determine "N", the number of prototypical bell sounds available.
- Set CV 55.3.1 to a number from "0" to "N". Selection "1" is the original prototypical bell for this model; selection "0" is "Feedback Bell[102]".
- If you set CV 55.3.1 to a value larger than "N", the decoder will revert to "0", the "Feedback Bell".
- If you set CV 55.3.1 to 1…N in Ops Mode, and the locomotive's bell is ringing, the newly selected prototypical bell will begin ringing immediately.

101 The default for some European models is 0, because their prototype did not have a bell.

102 Feedback Bells produce a single light "ding" when turning the bell on and a double "ding" when shutting the bell off. This bell type is suitable for locos that are not intended to have bells but need a bell sound to indicated that the bell state is on or off.

5.7.3 CV 55.70.SI Headlight

Three features can be assigned to function keys to control headlight operation:

Feature ID	Feature Name	Use
70	Automatic Headlight Activate	Activate/Deactivate Automatic Control of the Headlight
71	Headlight On	Explicitly turn the Headlight On/Off
72	Headlight Dim	Explicitly specify the Headlight be Dim/Bright

The headlight intensity (Off, Dim*, Bright) can be controlled automatically or explicitly.

Automatic Control

When the Feature 70 function state is 1, automatic control is activated. The headlight intensity changes automatically in response to changes to the locomotive's motive state.

Forward	Neutral from Forward	Reverse	Neutral from Reverse
Bright	Dim*	Dim*	Dim*

The automatic behavior can be configured in CV 55.70.1.

Feature 70 has precedence over Features 71 and 72. When the Feature 70 function state is 1, the Feature 71 and 72 function states are ignored.

Explicit Control

When the Feature 70 function state is 0, automatic control is deactivated. The headlight intensity reverts to the Feature 71 and 72 function states.

Feature 72 Function State	Feature 71 Function State	Intensity
X	0	Off
0	1	Bright
1	1	Dim*

Feature 70 has precedence over Features 71 and 72. If the Feature 70 function state changes to 1, because of a Feature 70 function key press or a start up operation, automatic control is re-activated.

Feature 71 has precedence over Feature 72. If the Feature 71 function state is 0, the Feature 72 function state is ignored.

* If the headlight cannot be dimmed, then Dim = Off.

5.7.3.1 CV 55.70.0 Headlight Initial State

Use this CV to specify the startup state function states for the Headlight features.

Default Value: **1**

CV 55.70.0: Headlight Initial State

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Reserved	Reserved	Feature 72 Function State	Feature 71 Function State	Feature 70 Function State

- Default value = 00000001 binary = 01 hex = 1 decimal (Automatic Control Activated).
- Bit 0 is the initial state of the Automatic Headlight Activate (Feature 70) function.
- Bit 1 is the initial state of the Headlight On (Feature 71) function.
- Bit 2 is the initial state of the Headlight Dim (Feature 72) function.
- A write to this CV in operations mode causes the Feature 70, 71 and 72 function states to be immediately set to the new values.
- A start up operation causes the Feature 70, 71 and 72 function states to be set to the values in this CV.

5.7.3.2 CV 55.70.1 Automatic Headlight Configuration

Use this CV to configure the Automatic Headlight behavior.

Default Value: **86**

CV 55.70.1: Automatic Headlight Configuration

NFR		REV		NFF		FWD	
Bit 7	**Bit 6**	**Bit 5**	**Bit 4**	**Bit 3**	**Bit 2**	**Bit 1**	**Bit 0**
Intensity	Intensity	Intensity	Intensity	Intensity	Intensity	Intensity	Intensity

- Default value = 01010110 binary = 56 hex = 86 decimal.
- Bits 0,1 specify the headlight intensity in FWD, bits 2,3 the intensity in NFF, bits 4,5 the intensity in REV, and bits 6,7 the intensity in NFR.

Bit 1 Bit 3 Bit 5 Bit 7	**Bit 0 Bit 2 Bit 4 Bit 6**	**Intensity**
0	0	Off
0	1	Dim*
1	0	Bright
1	1	Reserved

- The default settings specify the following behavior:

FWD	NFF	REV	NFR
Bright	Dim*	Dim*	Dim*

* If the headlight cannot be dimmed, then Dim = Off.

5.7.3.3 CV 55.70.10 Headlight Dim Intensity

For models with a dimmable Headlight, this CV controls its dim intensity.

Default Value: **Depends on Locomotive**

CV 55.70.10: Headlight Dim Intensity

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- The default value is dependent on the model.
- Valid values are 0…255, 0 being least intense (off) and 255 being most intense (bright).
- In Ops mode, with the Headlight dimmed, you can observe the Headlight intensity change as you change the value of CV 55.70.10.

5.7.3.4 CV 55.70.12 Headlight Max Intensity[103]

For models with a 256 intensity level Headlight, this CV controls its intensity when it's state is "bright".

Default Value:	**255**

CV 55.70.12: Headlight Max Intensity

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- Valid values are 0…255, 0 being least intense (off) and 255 being most intense (bright).
- In Ops mode, with the Headlight state "bright", you can observe the Headlight intensity change as you change the value of CV 55.70.12.

[103] This CV is currently supported only by Q2 firmware for the Quantum Revolution.

5.7.3.5 CV 55.70.SI Headlight Examples

Example 1: I want the automatic headlight to be bright in all four motive states, NFF, REV and NFR as well as FWD.

Solution: Set CV 55.70.1 to 10101010 binary = AA hex = 170 decimal.

Example 2: How will the headlight behave if I set CV 55.70.0 to 00000111 binary = 07 hex = 7 decimal?

Answer: The automatic headlight is initially activated and the headlight intensity is controlled by the CV 55.70.1 settings. If the automatic headlight is deactivated, for example, by pressing FL so that the FL function state is 0, then the Feature 71 function state turns the headlight on, and the Feature 72 function state makes the headlight dim.

Example 3: I want explicit headlight on/off control at all times. At startup I want the headlight off until I turn it on with a function key. When the headlight is on, it should be bright.

Solution: First set CV 55.70.0 to 0. Next remove the automatic headlight feature from multiple automatic lights #1 by setting CV 55.136.0 bit 0 to 0. Finally in CV 53 assign feature 71 to a function output.

Example 4: Same as example 3, but I want to explicitly dim the headlight as well. When I first turn the headlight on, it should be dim.

Solution: First set CV 55.70.0 to 00000100 binary = 04 hex = 4 decimal. Next remove the automatic headlight feature from multiple automatic lights #1 by setting CV 55.136.0 bit 0 to 0. Finally in CV 53 assign feature 71 to a function output and feature 72 to a second function output.

Example 5: I want explicit control over whether the headlight is bright or dim, but the headlight will always be on. On startup the headlight should be dim.

Solution: First set CV 55.70.0 to 00000110 binary = 05 hex = 5 decimal. Next remove the Automatic Headlight feature from Multiple Automatic Lights #1 by setting CV 55.136.0 bit 0 to 0. Finally in CV 53 assign feature 72 to a function output. You do not need to assign feature 71 to a function output.

5.7.4 CV 55.73.SI Reverse Light

Three features can be assigned to function keys to control reverse light operation:

Feature ID	Feature Name	Use
73	Automatic Reverse Light Activate	Activate/Deactivate Automatic Control of the Reverse Light
74	Reverse Light On	Explicitly turn the Reverse Light On/Off
75	Reverse Light Dim	Explicitly specify the Reverse Light be Dim/Bright

The reverse light intensity (Off, Dim*, Bright) can be controlled automatically or explicitly.

Automatic Control

When the Feature 73 function state is 1, automatic control is activated. The reverse light intensity changes automatically in response to changes to the locomotive's motive state.

Forward	Neutral from Forward	Reverse	Neutral from Reverse
Dim*	Dim*	Bright	Dim*

The automatic behavior can be configured in CV 55.73.1.

Feature 73 has precedence over Features 74 and 75. When the Feature 73 function state is 1, the Feature 74 and 75 function states are ignored.

Explicit Control

When the Feature 73 function state is 0, automatic control is deactivated. The reverse light intensity changes in response to Feature 74 and 75 function key presses.

Feature 75 Function State	Feature 74 Function State	Intensity
X	0	Off
0	1	Bright
1	1	Dim*

If the Feature 73 function state changes to 1, because of a Feature 73 function key press or a start up operation, automatic control is re-activated.

Feature 74 has precedence over Feature 75. If the Feature 74 function state is 0, the Feature 75 function state is ignored.

* If the reverse light cannot be dimmed, then Dim = Off.

5.7.4.1 CV 55.73.0 Reverse Light Initial State

Use this CV to specify the startup state function states for the Reverse Light features.

Default Value: **1**

CV 55.73.0: Reverse Light Initial State

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Reserved	Reserved	Feature 75 Function State	Feature 74 Function State	Feature 73 Function State

- Default value = 00000001 binary = 01 hex = 1 decimal (Automatic Control Activated).
- Bit 0 is the initial state of the Automatic Reverse Light Activate (Feature 73) function.
- Bit 1 is the initial state of the Reverse Light On (Feature 74) function.
- Bit 2 is the initial state of the Reverse Light Dim (Feature 75) function.
- A write to this CV in operations mode causes the Feature 73, 74 and 75 function states to be immediately set to the new values.
- A start up operation causes the Feature 73, 74 and 75 function states to be set to the values in this CV.

5.7.4.2 CV 55.73.1 Automatic Reverse Light Configuration

Use this CV to configure the Automatic Reverse Light behavior.

Default Value: **101**

CV 55.73.1: Automatic Reverse Light Configuration

NFR		REV		NFF		FWD	
Bit 7	**Bit 6**	**Bit 5**	**Bit 4**	**Bit 3**	**Bit 2**	**Bit 1**	**Bit 0**
Intensity	Intensity	Intensity	Intensity	Intensity	Intensity	Intensity	Intensity

- Default value = 01100101 binary = 65 hex = 101 decimal.
- Bits 0,1 specify the reverse light intensity in FWD, bits 2,3 the intensity in NFF, bits 4,5 the intensity in REV, and bits 6,7 the intensity in NFR.

Bit 1 Bit 3 Bit 5 Bit 7	**Bit 0 Bit 2 Bit 4 Bit 6**	**Intensity**
0	0	Off
0	1	Dim*
1	0	Bright
1	1	Reserved

- The default settings specify the behavior:

FWD	NFF	REV	NFR
Dim*	Dim*	Bright	Dim*

* If the reverse light cannot be dimmed, then Dim = Off.

5.7.4.3 CV 55.73.10 Reverse Light Dim Intensity

For models with a dimmable Reverse Light, this CV controls its dim intensity.

Default Value: **Depends on Locomotive**

CV 55.73.10: Reverse Light Dim Intensity

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	D6	D5	D4	D3	D2	D1	D0

- The default value is dependent on the model.
- Valid values are 0…255, 0 being least intense (off) and 255 being most intense (bright).
- In Ops mode, with the Reverse Light dimmed, you can observe the Reverse Light intensity change as you change the value of CV 55.73.10.

5.7.4.4 CV 55.73.12 Reverse Light Max Intensity[104]

For models with a 256 intensity level Reverse Light, this CV controls its intensity when it's state is "bright".

Default Value:	**255**

CV 55.73.12: Reverse Light Max Intensity

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- Valid values are 0…255, 0 being least intense (off) and 255 being most intense (bright).
- In Ops mode, with the Reverse Light state "bright", you can observe the Reverse Light intensity change as you change the value of CV 55.73.12.

[104] This CV is currently supported only by Q2 firmware for the Quantum Revolution.

5.7.4.5 CV 55.73.SI Reverse Light Examples

Example 1: I want the automatic reverse light to be bright in all four motive states, NFF, REV and NFR as well as FWD.

Solution: Set CV 55.73.1 to 10101010 binary = AA hex = 170 decimal.

Example 2: How will the reverse light behave if I set CV 55.73.0 to 00000111 binary = 07 hex = 7 decimal?

Answer: The automatic reverse light is initially activated and the reverse light intensity is controlled by the CV 55.73.1 settings. If the automatic reverse light is deactivated, for example, by pressing FL so that the FL function state is 0, then the Feature 74 function state turns the reverse light on, and the Feature 75 function state makes the reverse light dim.

Example 3: I want explicit reverse light on/off control at all times. At startup I want the reverse light off until I turn it on with a function key. When the reverse light is on, it should be bright.

Solution: First set CV 55.73.0 to 0. Next remove the automatic reverse light feature from multiple automatic lights #1 by setting CV 55.136.0 bit 1 to 0. Finally in CV 53 assign Feature 74 to a function output.

Example 4: Same as example 3, but I want to explicitly dim the reverse light as well. When I first turn the reverse light on, it should be dim.

Solution: First set CV 55.73.0 to 00000100 binary = 04 hex = 4 decimal. Next remove the automatic reverse light feature from multiple automatic lights #1 by setting CV 55.136.0 bit 1 to 0. Finally in CV 53 assign Feature 74 to a function output and Feature 75 to a second function output.

5.7.5 CV 55.76.SI Mars Light

Four features can be assigned to function keys to control mars light operation:

Feature ID	Feature Name	Use
76	Automatic Mars Light Activate	Activate/Deactivate Automatic Control of the Mars Light
77	Mars Light On	Explicitly turn the Mars Light On/Off
78	Mars Light Dim	Explicitly specify the Mars Light be Dim/Bright
79	Mars Light Strobe	Explicitly turn on/off Mars Light strobe

The mars light intensity (Off, Dim, Bright, Strobe) can be controlled automatically or explicitly.

Automatic Control

When the Feature 76 function state is 1, automatic control is activated. The mars light intensity changes automatically in response to changes to the locomotive's motive state.

Forward	Neutral from Forward	Reverse	Neutral from Reverse
Strobe	Dim	Dim	Dim

The automatic behavior can be configured in CV 55.76.1, CV 55.76.2, CV 55.76.3, and CV 55.76.4.

Feature 76 has precedence over Features 77, 78 and 79. When the Feature 76 function state is 1, the Feature 77, 78 and 79 function states are ignored.

Explicit Control

When the Feature 76 function state is 0, automatic control is deactivated. The Mars Light intensity changes in response to Feature 77, 78 and 79 function key presses.

Feature 79 Function State	Feature 78 Function State	Feature 77 Function State	Intensity
x	X	0	Off
0	0	1	Bright
0	1	1	Dim
1	X	1	Strobe

Feature 76 has precedence over Features 77, 78 and 79. If the Feature 76 function state changes to 1, because of a Feature 76 function key press or a start up operation, automatic control is re-activated.

Feature 77 has precedence over Features 78 and 79. If the Feature 77 function state is 0, the Feature 78 and 79 function states are ignored.

Feature 79 has precedence over Feature 78. If the Feature 79 function state is 1, the Feature 78 function state is ignored.

5.7.5.1 CV 55.76.0 Mars Light Initial State

Use this CV to specify the startup state function states for the Mars Light features.

Default Value: **1**

CV 55.76.0: Mars Light Initial State

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Reserved	Feature 79 Function State	Feature 78 Function State	Feature 77 Function State	Feature 76 Function State

- Default value = 00000001 binary = 01 hex = 1 decimal (Automatic Control Activated).
- Bit 0 is the initial state of the Automatic Mars Light Activate (Feature 76) function.
- Bit 1 is the initial state of the Mars Light On (Feature 77) function.
- Bit 2 is the initial state of the Mars Light Dim (Feature 78) function.
- Bit 3 is the initial state of the Mars Light Strobe (Feature 79) function.
- A write to this CV in operations mode causes the Feature 76, 77, 78 and 79 function states to be immediately set to the new values.
- A start up operation causes the Feature 76, 77, 78 and 79 function states to be set to the values in this CV.

5.7.5.2 CV 55.76.1 Automatic Mars Light FWD Configuration

Use this CV to configure how the Automatic Mars Light behaves when the locomotive is in forward.

Default Value: **3**

CV 55.76.1: Automatic Mars Light FWD Configuration

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Intensity	Intensity

- Default value = 00000011 binary = 03 hex = 3 decimal (strobe).
- Bits 0 and 1 specify the mars light intensity.

Bit 1	Bit 0	Intensity
0	0	Off
0	1	Dim
1	0	Bright
1	1	Strobe

5.7.5.3 CV 55.76.2 Automatic Mars Light NFF Configuration

Use this CV to configure how the Automatic Mars Light behaves when the locomotive is in neutral from forward.

Default Value: **1**

CV 55.76.2: Automatic Mars Light NFF Configuration

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Intensity	Intensity

- Default value = 00000001 binary = 01 hex = 1 decimal (dim).
- Bits 0 and 1 specify the mars light intensity.

Bit 1	Bit 0	Intensity
0	0	Off
0	1	Dim
1	0	Bright
1	1	Strobe

5.7.5.4 CV 55.76.3 Automatic Mars Light REV Configuration

Use this CV to configure how the Automatic Mars Light behaves when the locomotive is in reverse.

Default Value: **1**

CV 55.76.3: Automatic Mars Light REV Configuration

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Intensity	Intensity

- Default value = 00000001 binary = 01 hex = 1 decimal (dim).
- Bits 0 and 1 specify the mars light intensity.

Bit 1	Bit 0	Intensity
0	0	Off
0	1	Dim
1	0	Bright
1	1	Strobe

5.7.5.5 CV 55.76.4 Automatic Mars Light NFR Configuration

Use this CV to configure how the Automatic Mars Light behaves when the locomotive is in neutral from reverse.

Default Value: **1**

CV 55.76.4: Automatic Mars Light NFR Configuration

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Intensity	Intensity

- Default value = 00000001 binary = 01 hex = 1 decimal (dim).
- Bits 0 and 1 specify the mars light intensity.

Bit 1	Bit 0	Intensity
0	0	Off
0	1	Dim
1	0	Bright
1	1	Strobe

5.7.5.6 CV 55.76.6 Mars Light Strobe Period[105]

For models with a Mars Light, this CV controls its strobe rate.

Default Value:	**100**

CV 55.76.6: Mars Light Strobe Period

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- Valid values are 2…255. Each unit represents 0.01 second. A value of 100 represents 1.00 second. If the value of this CV is 0 or 1, a period of 0.02 second is used.
- The CV value is the time for one complete strobe cycle to complete.
- In Ops mode, with the Mars Light strobing, you can observe the Mars Light strobe rate change as you change the value of CV 55.76.6.

[105] This CV is currently supported only by Q2 firmware for the Quantum Revolution.

5.7.5.7 CV 55.76.10 Mars Light Dim Intensity

For models with a Mars Light, this CV controls its dim intensity.

Default Value: **Depends on Locomotive**

CV 55.76.10: Mars Light Dim Intensity

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- The default value is dependent on the model.
- Valid values are 0…255, 0 being least intense (off) and 255 being most intense (bright).
- In Ops mode, with the Mars Light dimmed, you can observe the Mars Light intensity change as you change the value of CV 55.76.10.

5.7.5.8 CV 55.76.11 Mars Light Min Intensity[106]

For models with a Mars Light, this CV controls its minimum brightness when it's state is "strobing".

Default Value:	4

CV 55.76.11: Mars Light Min Intensity

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	D6	D5	D4	D3	D2	D1	D0

- Valid values are 0…255, 0 being least intense (off) and 255 being most intense (bright). For best results, set CV55.76.11 to a value less than the value of CV55.76.13.
- In Ops mode, with the Mars Light strobing, you can observe the intensity change as you change the value of CV 55.76.11.

[106] This CV is currently supported only by Q2 firmware for the Quantum Revolution.

5.7.5.9 CV 55.76.12 Mars Light Max Intensity[107]

For models with a Mars Light, this CV controls its intensity when it's state is "bright" or "strobing".

Default Value:	**255**

CV 55.76.12: Mars Light Max Intensity

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- Valid values are 0…255, 0 being least intense (off) and 255 being most intense (bright). For best results, set CV55.76.12 to a value greater than the value of CV55.76.13.
- In Ops mode, with the Mars Light bright or strobing, you can observe the Mars Light intensity change as you change the value of CV 55.76.12.

[107] This CV is currently supported only by Q2 firmware for the Quantum Revolution.

5.7.5.10 CV 55.76.13 Mars Light Mid Intensity[108]

For models with a Mars Light, this CV controls the brightness of the secondary strobe pulse.

Default Value:	**32**

CV 55.76.13: Mars Light Mid Intensity

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- Valid values are 0…255, 0 being least intense (off) and 255 being most intense (bright). For best results, set CV55.76.13 to a value greater than the value of CV55.76.11 and less than the value of CV55.76.12.
- In Ops mode, with the Mars Light strobing, you can observe the intensity of the secondary strobe pulse change as you change the value of CV 55.76.13.

[108] This CV is currently supported only by Q2 firmware for the Quantum Revolution.

5.7.5.11 CV 55.76.SI Mars Light Examples

Example 1: I want the automatic mars light to be bright (not strobing) in all four motive states, NFF, REV and NFR as well as FWD.

Solution: Set CV 55.76.1…4 to 00000010 binary = 02 hex = 2 decimal.

Example 2: How will the mars light behave if I set CV 55.76.0 to 00001111 binary = 0F hex = 15 decimal?

Answer: The automatic mars light is initially activated and the mars light intensity is controlled by the CV 55.76.1…4 settings. If the automatic mars light is deactivated, for example, by pressing FL so that the FL function state is 0, then the Feature 77 function state turns the mars light on, and the Feature 79 function state makes the mars light strobe.

Example 3: I want explicit mars light on/off control at all times. At startup I want the mars light off until I turn it on with a function key. When the mars light is on, it should strobe.

Solution: First set CV 55.76.0 to 00001000 binary = 08 hex = 8 decimal. Next remove the automatic mars light feature from multiple automatic lights #1 by setting CV 55.136.0 bit 2 to 0. Finally in CV 53 assign Feature 77 to a function output.

Example 4: Same as example 3, but I want to explicitly dim and strobe the mars light as well. When I first turn the mars light on, it should be dim.

Solution: First set CV 55.76.0 to 00000100 binary = 04 hex = 4 decimal. Next remove the automatic mars light feature from multiple automatic lights #1 by setting CV 55.136.0 bit 2 to 0. Finally in CV 53 assign Feature 77 to a function output, Feature 78 to a second function output, and Feature 79 to a third function output.

Example 5: I want to explicitly dim and strobe the mars light, but the mars light should be always on. On startup, the mars light should be dim.

Solution: First set CV 55.76.0 to 00000110 binary = 05 hex = 5 decimal. Next remove the Automatic Mars Light feature from Multiple Automatic Lights #1 by setting CV 55.136.0 bit 2 to 0. Finally in CV 53 assign Feature 78 to a function output and Feature 79 to a second function output. You do not need to assign Feature 77 to a function output.

5.7.6 CV 55.80.SI Rear Mars Light

Four features can be assigned to function keys to control Rear Mars Light operation:

Feature ID	Feature Name	Use
80	Automatic Rear Mars Light Activate	Activate/Deactivate Automatic Control of the Rear Mars Light
81	Rear Mars Light On	Explicitly turn the Rear Mars Light On/Off
82	Rear Mars Light Dim	Explicitly specify the Rear Mars Light be Dim/Bright
83	Rear Mars Light Strobe	Explicitly turn on/off Rear Mars Light strobe

The rear mars light intensity (Off, Dim, Bright, Strobe) can be controlled automatically or explicitly.

Automatic Control

When the Feature 80 function state is 1, automatic control is activated. The rear mars light intensity changes automatically in response to changes to the locomotive's motive state.

Forward	Neutral from Forward	Reverse	Neutral from Reverse
Strobe	Dim	Dim	Dim

The automatic behavior can be configured in CV 55.80.1, CV 55.80.2, CV 55.80.3, and CV 55.80.4.

Feature 80 has precedence over Features 81, 82 and 83. When the Feature 80 function state is 1, the Feature 81, 82 and 83 function states are ignored.

Explicit Control

When the Feature 80 function state is 0, automatic control is deactivated. The Rear Mars Light intensity changes in response to Feature 81, 82 and 83 function key presses.

Feature 83 Function State	Feature 82 Function State	Feature 81 Function State	Intensity
x	X	0	Off
0	0	1	Bright
0	1	1	Dim
1	X	1	Strobe

Feature 80 has precedence over Features 81, 82 and 83. If the Feature 80 function state changes to 1, because of a Feature 80 function key press or a start up operation, automatic control is re-activated.

Feature 81 has precedence over Features 82 and 83. If the Feature 81 function state is 0, the Feature 82 and 83 function states are ignored.

Feature 83 has precedence over Feature 82. If the Feature 83 function state is 1, the Feature 82 function state is ignored.

5.7.6.1 CV 55.80.0 Rear Mars Light Initial State

Use this CV to specify the startup state function states for the Rear Mars Light features.

Default Value: **1**

CV 55.80.0: Rear Mars Light Initial State

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Reserved	Feature 83 Function State	Feature 82 Function State	Feature 81 Function State	Feature 80 Function State

- Default value = 00000001 binary = 01 hex = 1 decimal (Automatic Control Activated).
- Bit 0 is the initial state of the Automatic Rear Mars Light Activate (Feature 80) function.
- Bit 1 is the initial state of the Rear Mars Light On (Feature 81) function.
- Bit 2 is the initial state of the Rear Mars Light Dim (Feature 82) function.
- Bit 3 is the initial state of the Rear Mars Light Strobe (Feature 83) function.
- A write to this CV in operations mode causes the Feature 80, 81, 82 and 83 function states to be immediately set to the new values.
- A start up operation causes the Feature 80, 81, 82 and 83 function states to be set to the values in this CV.

5.7.6.2 CV 55.80.1 Automatic Rear Mars Light FWD Configuration

Use this CV to configure how the Automatic Rear Mars Light behaves when the locomotive is in forward.

Default Value: **1**

CV 55.80.1: Automatic Rear Mars Light FWD Configuration

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Intensity	Intensity

- Default value = 00000001 binary = 01 hex = 1 decimal (dim).
- Bits 0 and 1 specify the Rear Mars Light intensity.

Bit 1	Bit 0	Intensity
0	0	Off
0	1	Dim
1	0	Bright
1	1	Strobe

5.7.6.3 CV 55.80.2 Automatic Rear Mars Light NFF Configuration

Use this CV to configure how the Automatic Rear Mars Light behaves when the locomotive is in neutral from forward.

Default Value: **1**

CV 55.80.2: Automatic Rear Mars Light NFF Configuration

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Intensity	Intensity

- Default value = 00000001 binary = 01 hex = 1 decimal (dim).
- Bits 0 and 1 specify the Rear Mars Light intensity.

Bit 1	Bit 0	Intensity
0	0	Off
0	1	Dim
1	0	Bright
1	1	Strobe

5.7.6.4 CV 55.80.3 Automatic Rear Mars Light REV Configuration

Use this CV to configure how the Automatic Rear Mars Light behaves when the locomotive is in reverse.

Default Value: **3**

CV 55.80.3: Automatic Rear Mars Light REV Configuration

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Intensity	Intensity

- Default value = 00000011 binary = 03 hex = 3 decimal (strobe).
- Bits 0 and 1 specify the Rear Mars Light intensity.

Bit 1	Bit 0	Intensity
0	0	Off
0	1	Dim
1	0	Bright
1	1	Strobe

5.7.6.5 CV 55.80.4 Automatic Rear Mars Light NFR Configuration

Use this CV to configure how the Automatic Rear Mars Light behaves when the locomotive is in neutral from reverse.

Default Value: **1**

CV 55.80.4: Automatic Rear Mars Light NFR Configuration

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Intensity	Intensity

- Default value = 00000001 binary = 01 hex = 1 decimal (dim).
- Bits 0 and 1 specify the Rear Mars Light intensity.

Bit 1	Bit 0	Intensity
0	0	Off
0	1	Dim
1	0	Bright
1	1	Strobe

5.7.6.6 CV 55.80.6 Rear Mars Light Strobe Period[109]

For models with a Rear Mars Light, this CV controls its strobe rate.

Default Value:	**100**

CV 55.80.6: Rear Mars Light Strobe Period

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- Valid values are 2…255. Each unit represents 0.01 second. A value of 100 represents 1.00 second. If the value of this CV is 0 or 1, a period of 0.02 second is used.
- The CV value is the time for one complete strobe cycle to complete.
- In Ops mode, with the Rear Mars Light strobing, you can observe the Rear Mars Light strobe rate change as you change the value of CV 55.80.6.

[109] This CV is currently supported only by Q2 firmware for the Quantum Revolution.

5.7.6.7 CV 55.80.10 Rear Mars Light Dim Intensity

For models with a Rear Mars Light, this CV controls its dim intensity.

Default Value: **Depends on Locomotive**

CV 55.80.10: Rear Mars Light Dim Intensity

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	D6	D5	D4	D3	D2	D1	D0

- The default value is dependent on the model.
- Valid values are 0…255, 0 being least intense (off) and 255 being most intense (bright).
- In Ops mode, with the Rear Mars Light dimmed, you can observe the Rear Mars Light intensity change as you change the value of CV 55.80.10.

5.7.6.8 CV 55.80.11 Rear Mars Light Min Intensity[110]

For models with a Rear Mars Light, this CV controls its minimum brightness when it's state is "strobing".

Default Value:	**4**

CV 55.80.11: Rear Mars Light Min Intensity

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- Valid values are 0…255, 0 being least intense (off) and 255 being most intense (bright). For best results, set CV55.80.11 to a value less than the value of CV55.80.13.
- In Ops mode, with the Rear Mars Light strobing, you can observe the intensity change as you change the value of CV 55.80.11.

[110] This CV is currently supported only by Q2 firmware for the Quantum Revolution.

5.7.6.9 CV 55.80.12 Rear Mars Light Max Intensity[111]

For models with a Rear Mars Light, this CV controls its intensity when it's state is "bright" or "strobing".

Default Value:	**255**

CV 55.80.12: Rear Mars Light Max Intensity

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- Valid values are 0…255, 0 being least intense (off) and 255 being most intense (bright). For best results, set CV55.80.12 to a value greater than the value of CV55.80.13.
- In Ops mode, with the Rear Mars Light bright or strobing, you can observe the Rear Mars Light intensity change as you change the value of CV 55.80.12.

[111] This CV is currently supported only by Q2 firmware for the Quantum Revolution.

5.7.6.10 CV 55.80.13 Rear Mars Light Mid Intensity[112]

For models with a Rear Mars Light, this CV controls the brightness of the secondary strobe pulse.

Default Value:	**32**

CV 55.80.13: Rear Mars Light Mid Intensity

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- Valid values are 0…255, 0 being least intense (off) and 255 being most intense (bright). For best results, set CV55.80.13 to a value greater than the value of CV55.80.11 and less than the value of CV55.80.12.
- In Ops mode, with the Rear Mars Light strobing, you can observe the intensity of the secondary strobe pulse change as you change the value of CV 55.80.13.

[112] This CV is currently supported only by Q2 firmware for the Quantum Revolution.

5.7.6.11 CV 55.80.SI Rear Mars Light Examples

Example 1: I want the automatic rear mars light to be bright (not strobing) in all four motive states, NFF, REV and NFR as well as FWD.

Solution: Set CV 55.80.1…4 to 00000010 binary = 02 hex = 2 decimal.

Example 2: How will the rear mars light behave if I set CV 55.80.0 to 00001111 binary = 0F hex = 15 decimal?

Answer: The automatic rear mars light is initially activated and the rear mars light intensity is controlled by the CV 55.80.1…4 settings. If the automatic rear mars light is deactivated, for example, by pressing FL so that the FL function state is 0, then the Feature 81 function state turns the rear mars light on, and the Feature 83 function state makes the rear mars light strobe.

Example 3: I want explicit rear mars light on/off control at all times. At startup I want the rear mars light off until I turn it on with a function key. When the rear mars light is on, it should strobe.

Solution: First set CV 55.80.0 to 00001000 binary = 08 hex = 8 decimal. Next remove the automatic rear mars light feature from multiple automatic lights #1 by setting CV 55.136.0 bit 3 to 0. Finally in CV 53 assign Feature 81 to a function output.

Example 4: Same as example 3, but I want to explicitly dim and strobe the rear mars light as well. When I first turn the rear mars light on, it should be dim.

Solution: First set CV 55.80.0 to 00000100 binary = 04 hex = 4 decimal. Next remove the automatic rear mars light feature from multiple automatic lights #1 by setting CV 55.136.0 bit 3 to 0. Finally in CV 53 assign Feature 81 to a function output, Feature 82 to a second function output, and Feature 83 to a third function output.

Example 5: I want to explicitly dim and strobe the rear mars light, but the rear mars light should be always on. On startup, the rear mars light should be dim.

Solution: First set CV 55.80.0 to 00000110 binary = 05 hex = 5 decimal. Next remove the Automatic Rear Mars Light feature from Multiple Automatic Lights #1 by setting CV 55.136.0 bit 3 to 0. Finally in CV 53 assign Feature 82 to a function output and Feature 83 to a second function output. You do not need to assign Feature 81 to a function output.

5.7.7 CV 55.84.SI Ditch Lights

Four features can be assigned to function keys to control ditch lights operation:

Feature ID	Feature Name	Use
84	Automatic Ditch Lights Activate	Activate/Deactivate Automatic Control of the Ditch Lights
85	Ditch Lights On	Explicitly turn the Ditch Lights On/Off
86	Ditch Lights Dim	Explicitly specify the Ditch Lights be Dim/Bright
87	Ditch Lights Strobe	Explicitly turn on/off Ditch Lights strobe

The ditch lights intensity (Off, Dim, Bright, Strobe) can be controlled automatically or explicitly.

Automatic Control

When the Feature 84 function state is 1, automatic control is activated. The ditch lights intensity changes automatically in response to changes to the locomotive's motive state.

Forward	Neutral from Forward	Reverse	Neutral from Reverse
Bright	Off	Off	Off

The automatic behavior can be configured in CV 55.84.1, CV 55.84.2, CV 55.84.3, and CV 55.84.4.

Feature 84 has precedence over Features 85, 86 and 87. When the Feature 84 function state is 1, the Feature 85, 86 and 87 function states are ignored.

Explicit Control

When the Feature 84 function state is 0, automatic control is deactivated. The ditch lights intensity changes in response to Feature 85, 86 and 87 function key presses.

Feature 87 Function State	Feature 86 Function State	Feature 85 Function State	Intensity
X	X	0	Off
0	0	1	Bright
0	1	1	Dim*
1	X	1	Strobe

Feature 84 has precedence over Features 85, 86 and 87. If the Feature 84 function state changes to 1, because of a Feature 84 function key press or a start up operation, automatic control is re-activated.

Feature 85 has precedence over Features 86 and 87. If the Feature 85 function state is 0, the Feature 86 and 87 function states are ignored.

Feature 87 has precedence over Feature 86. If the Feature 87 function state is 1, the Feature 86 function state is ignored.

* If the ditch lights cannot be dimmed, then Dim = Off.

5.7.7.1 CV 55.84.0 Ditch Lights Initial State

Use this CV to specify the startup state function states for the Ditch Lights features.

Default Value: **1**

CV 55.84.0: Ditch Lights Initial State

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Strobe with Horn	Feature 87 Function State	Feature 86 Function State	Feature 85 Function State	Feature 84 Function State

- Default value = 00000001 binary = 01 hex = 1 decimal (Automatic Control Activated).
- Bit 0 is the initial state of the Automatic Ditch Lights Activate (Feature 84) function.
- Bit 1 is the initial state of the Ditch Lights On (Feature 85) function.
- Bit 2 is the initial state of the Ditch Lights Dim (Feature 86) function.
- Bit 3 is the initial state of the Ditch Lights Strobe (Feature 87) function.
- If bit 4 = 1, under explicit control the ditch lights strobe when the horn blows. Note that if the ditch lights are already strobing, no change in Ditch Lights behavior will be observed when the horn blows. Bit 4 is applied even if the Feature 85 function state is 0, but is ignored if the Feature 84 function state is 1.
- A write to this CV in operations mode causes the Feature 84, 85, 86 and 87 function states to be immediately set to the new values.
- A start up operation causes the Feature 84, 85, 86 and 87 function states to be set to the values in this CV.

5.7.7.2 CV 55.84.1 Automatic Ditch Lights FWD Configuration

Use this CV to configure how the Automatic Ditch Lights behave when the locomotive is in forward.

Default Value: **6**

CV 55.84.1: Automatic Ditch Lights FWD Configuration

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Reserved	Reserved	Strobe with Horn	Intensity	Intensity

- Default value = 00000110 binary = 06 hex = 6 decimal (bright, strobe with horn).
- Bits 0 and 1 specify the ditch lights intensity.

Bit 1	Bit 0	Intensity
0	0	Off
0	1	Dim*
1	0	Bright
1	1	Strobe

- If bit 2 = 1, the ditch lights strobe when the horn blows. Note that if the Intensity = Strobe, no change in ditch lights behavior will be observed when the horn blows.

* If the ditch lights cannot be dimmed, then Dim = Off.

5.7.7.3 CV 55.84.2 Automatic Ditch Lights NFF Configuration

Use this CV to configure how the Automatic Ditch Lights behave when the locomotive is in neutral from forward.

Default Value: **0**

CV 55.84.2: Automatic Ditch Lights NFF Configuration

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Reserved	Reserved	Strobe with Horn	Intensity	Intensity

- Default value = 00000000 binary = 00 hex = 0 decimal (off).
- Bits 0 and 1 specify the ditch lights intensity.

Bit 1	Bit 0	Intensity
0	0	Off
0	1	Dim*
1	0	Bright
1	1	Strobe

- If bit 2 = 1, the ditch lights strobe when the horn blows. Note that if the Intensity = Strobe, no change in ditch lights behavior will be observed when the horn blows.

* If the ditch lights cannot be dimmed, then Dim = Off.

5.7.7.4 CV 55.84.3 Automatic Ditch Lights REV Configuration

Use this CV to configure how the Automatic Ditch Lights behave when the locomotive is in reverse.

Default Value: **0**

CV 55.84.3: Automatic Ditch Lights REV Configuration

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Reserved	Reserved	Strobe with Horn	Intensity	Intensity

- Default value = 00000000 binary = 00 hex = 0 decimal (off).
- Bits 0 and 1 specify the ditch lights intensity.

Bit 1	Bit 0	Intensity
0	0	Off
0	1	Dim*
1	0	Bright
1	1	Strobe

- If bit 2 = 1, the ditch lights strobe when the horn blows. Note that if the Intensity = Strobe, no change in ditch lights behavior will be observed when the horn blows.

* If the ditch lights cannot be dimmed, then Dim = Off.

5.7.7.5 CV 55.84.4 Automatic Ditch Lights NFR Configuration

Use this CV to configure how the Automatic Ditch Lights behave when the locomotive is in neutral from reverse.

Default Value: **0**

CV 55.84.4: Automatic Ditch Lights NFR Configuration

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Reserved	Reserved	Strobe with Horn	Intensity	Intensity

- Default value = 00000000 binary = 00 hex = 0 decimal (off).
- Bits 0 and 1 specify the ditch lights intensity.

Bit 1	Bit 0	Intensity
0	0	Off
0	1	Dim*
1	0	Bright
1	1	Strobe

- If bit 2 = 1, the ditch lights strobe when the horn blows. Note that if the Intensity = Strobe, no change in ditch lights behavior will be observed when the horn blows.

* If the ditch lights cannot be dimmed, then Dim = Off.

5.7.7.6 CV 55.84.5 Ditch Lights Strobe Hold Time

Use this CV to specify the number of seconds the ditch lights continue to strobe after a horn blast ends.

Default Value: **5**

CV 55.84.5: Ditch Lights Strobe Hold Time

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Hold Time	Hold Time	Hold Time	Hold Time	Hold Time

- Default value = 00000101 binary = 05 hex = 5 decimal.
- Valid values are 0…31 seconds.

5.7.7.7 CV 55.84.6 Ditch Lights Strobe Period[113]

For models with Ditch Lights, this CV controls their strobe rate.

Default Value:	**100**

CV 55.84.6: Ditch Lights Strobe Period

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- Valid values are 2…255. Each unit represents 0.01 second. A value of 100 represents 1.00 second. If the value of this CV is 0 or 1, a period of 0.02 second is used.
- The CV value is the time for one complete strobe cycle of both ditch lights to complete.
- In Ops mode, with the Ditch Lights strobing, you can observe the strobe rate change as you change the value of CV 55.84.6.

[113] This CV is currently supported only by Q2 firmware for the Quantum Revolution.

5.7.7.8 CV 55.84.10 Ditch Lights Dim Intensity

For models with dimmable Ditch Lights, this CV controls the dim intensity.

Default Value: **Depends on Locomotive**

CV 55.84.10: Ditch Lights Dim Intensity

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	D6	D5	D4	D3	D2	D1	D0

- The default value is dependent on the model.
- Valid values are 0…255, 0 being least intense (off) and 255 being most intense (bright).
- In Ops mode, with the Ditch Lights dimmed, you can observe the Ditch Lights intensity change as you change the value of CV 55.84.10.

5.7.7.9 CV 55.84.12 Ditch Lights Max Intensity[114]

For models with 256 intensity level Ditch Lights, this CV controls its intensity when it's state is "bright" or "strobing".

Default Value:	**255**

CV 55.84.12: Ditch Lights Max Intensity

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- Valid values are 0…255, 0 being least intense (off) and 255 being most intense (bright).
- In Ops mode, with the Ditch Lights state "bright" or "strobing", you can observe the Ditch Lights intensity change as you change the value of CV 55.84.12.

[114] This CV is currently supported only by Q2 firmware for the Quantum Revolution.

5.7.7.10 CV 55.84.SI Ditch Lights Examples

Example 1: I want the automatic ditch lights to be bright (not strobing) in all four motive states, NFF, REV and NFR as well as FWD. I want the ditch lights to strobe when the horn blows in both FWD and REV.

Solution: Set CV 55.84.1 and CV 55.84.3 to 00000110 binary = 06 hex = 6 decimal. Set CV 55.84.2 and CV 55.84.4 to 00000010 binary = 02 hex = 2 decimal.

Example2: I want the automatic ditch lights to be off in all four motive states. But I want the ditch lights to strobe when the horn blows in both FWD and REV.

Solution: Set CV 55.84.1 and CV 55.84.3 to 00000100 binary = 04 hex = 4 decimal. Set CV 55.84.2 and CV 55.84.4 to 0.

Example 3: How will the ditch lights behave if I set CV 55.84.0 to 00011111 binary = 1F hex = 31 decimal?

Answer: The automatic ditch lights are initially activated and the ditch lights intensity is controlled by the CV 55.84.1…4 settings. If the automatic ditch lights are deactivated, for example, by pressing FL so that the FL function state is 0, then the Feature 85 function state turns the ditch lights on, and the Feature 87 function state makes the ditch lights strobe.

Example 4: I want explicit ditch lights on/off control at all times. At startup I want the ditch lights off until I turn them on with a function key. When the ditch lights are on, they should be bright (not strobing).

Solution: First set CV 55.84.0 to 0. Next remove the automatic ditch lights feature from multiple automatic lights #1 by setting CV 55.136.0 bit 4 to 0. Finally in CV 53 assign Feature 85 to a function output.

Example 5: Same as example 4, but I want to explicitly dim and strobe the ditch lights as well. When I first turn the ditch lights on, they should be bright.

Solution: First set CV 55.84.0 to 0. Next remove the automatic ditch lights feature from multiple automatic lights #1 by setting CV 55.136.0 bit 4 to 0. Finally in CV 53 assign Feature 85 to a function output, Feature 86 to a second function output, and Feature 87 to a third function output.

Example 6: I want to explicitly strobe the ditch lights, but when not strobing the ditch lights should be always bright.

Solution: First set CV 55.84.0 to 00000010 binary = 02 hex = 2 decimal. Next remove the Automatic Ditch Lights feature from Multiple Automatic Lights #1 by setting CV 55.136.0 bit 4 to 0. Finally in CV 53 assign Feature 87 to a function output. You do not need to assign Feature 85 to a function output.

Example7: Similar to example 2, I want the automatic ditch lights to be off in all four motive states. But I want the ditch lights to strobe when the horn blows in FWD only. Further, I want this behavior even if FL is 0.

Solution: First set CV 55.84.0 to 1. Then set CV 55.84.1 to 00000100 binary = 04 hex = 4 decimal. Set CV 55.84.2, CV 55.84.3 and CV 55.84.4 to 0. Finally remove the Automatic Ditch Lights feature from Multiple Automatic Lights #1 by setting CV 55.136.0 bit 4 to 0.

5.7.8 CV 55.88.SI Rear Ditch Lights

Four features can be assigned to function keys to control Rear Ditch Lights operation:

Feature ID	Feature Name	Use
88	Automatic Rear Ditch Lights Activate	Activate/Deactivate Automatic Control of the Rear Ditch Lights
89	Rear Ditch Lights On	Explicitly turn the Rear Ditch Lights On/Off
90	Rear Ditch Lights Dim	Explicitly specify the Rear Ditch Lights be Dim/Bright
91	Rear Ditch Lights Strobe	Explicitly turn on/off Rear Ditch Lights strobe

The Rear Ditch Lights intensity (Off, Dim, Bright, Strobe) can be controlled automatically or explicitly.

Automatic Control

When the Feature 88 function state is 1, automatic control is activated. The Rear Ditch Lights intensity changes automatically in response to changes to the locomotive's motive state.

Forward	Neutral from Forward	Reverse	Neutral from Reverse
Bright	Off	Off	Off

The automatic behavior can be configured in CV 55.88.1, CV 55.88.2, CV 55.88.3, and CV 55.88.4.

Feature 88 has precedence over Features 89, 90 and 91. When the Feature 88 function state is 1, the Feature 89, 90 and 91 function states are ignored.

Explicit Control

When the Feature 88 function state is 0, automatic control is deactivated. The Rear Ditch Lights intensity changes in response to Feature 89, 90 and 91 function key presses.

Feature 91 Function State	Feature 90 Function State	Feature 89 Function State	Intensity
X	X	0	Off
0	0	1	Bright
0	1	1	Dim*
1	X	1	Strobe

Feature 88 has precedence over Features 89, 90 and 91. If the Feature 88 function state changes to 1, because of a Feature 88 function key press or a start up operation, automatic control is re-activated.

Feature 89 has precedence over Features 90 and 91. If the Feature 89 function state is 0, the Feature 90 and 91 function states are ignored.

Feature 91 has precedence over Feature 90. If the Feature 91 function state is 1, the Feature 90 function state is ignored.

* If the Rear Ditch Lights cannot be dimmed, then Dim = Off.

5.7.8.1 CV 55.88.0 Rear Ditch Lights Initial State

Use this CV to specify the startup state function states for the Rear Ditch Lights features.

Default Value: **1**

CV 55.88.0: Rear Ditch Lights Initial State

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Strobe with Horn	Feature 91 Function State	Feature 90 Function State	Feature 89 Function State	Feature 88 Function State

- Default value = 00000001 binary = 01 hex = 1 decimal (Automatic Control Activated).
- Bit 0 is the initial state of the Automatic Rear Ditch Lights Activate (Feature 88) function.
- Bit 1 is the initial state of the Rear Ditch Lights On (Feature 89) function.
- Bit 2 is the initial state of the Rear Ditch Lights Dim (Feature 90) function.
- Bit 3 is the initial state of the Rear Ditch Lights Strobe (Feature 91) function.
- If bit 4 = 1, under explicit control the Rear Ditch Lights strobe when the horn blows. Note that if the Rear Ditch Lights are already strobing, no change in Rear Ditch Lights behavior will be observed when the horn blows. Bit 4 is applied even if the Feature 89 function state is 0, but is ignored if the Feature 88 function state is 1.
- A write to this CV in operations mode causes the Feature 88, 89, 90 and 91 function states to be immediately set to the new values.
- A start up operation causes the Feature 88, 89, 90 and 91 function states to be set to the values in this CV.

5.7.8.2 CV 55.88.1 Automatic Rear Ditch Lights FWD Configuration

Use this CV to configure how the Automatic Rear Ditch Lights behave when the locomotive is in forward.

Default Value: **0**

CV 55.88.1: Automatic Rear Ditch Lights FWD Configuration

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Reserved	Reserved	Strobe with Horn	Intensity	Intensity

- Default value = 00000000 binary = 00 hex = 0 decimal (off).
- Bits 0 and 1 specify the Rear Ditch Lights intensity.

Bit 1	Bit 0	Intensity
0	0	Off
0	1	Dim*
1	0	Bright
1	1	Strobe

- If bit 2 = 1, the Rear Ditch Lights strobe when the horn blows. Note that if the Intensity = Strobe, no change in Rear Ditch Lights behavior will be observed when the horn blows.

* If the Rear Ditch Lights cannot be dimmed, then Dim = Off.

5.7.8.3 CV 55.88.2 Automatic Rear Ditch Lights NFF Configuration

Use this CV to configure how the Automatic Rear Ditch Lights behave when the locomotive is in neutral from forward.

Default Value: **0**

CV 55.88.2: Automatic Rear Ditch Lights NFF Configuration

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Reserved	Reserved	Strobe with Horn	Intensity	Intensity

- Default value = 00000000 binary = 00 hex = 0 decimal (off).
- Bits 0 and 1 specify the Rear Ditch Lights intensity.

Bit 1	Bit 0	Intensity
0	0	Off
0	1	Dim*
1	0	Bright
1	1	Strobe

- If bit 2 = 1, the Rear Ditch Lights strobe when the horn blows. Note that if the Intensity = Strobe, no change in Rear Ditch Lights behavior will be observed when the horn blows.

* If the Rear Ditch Lights cannot be dimmed, then Dim = Off.

5.7.8.4 CV 55.88.3 Automatic Rear Ditch Lights REV Configuration

Use this CV to configure how the Automatic Rear Ditch Lights behave when the locomotive is in reverse.

Default Value: **6**

CV 55.88.3: Automatic Rear Ditch Lights REV Configuration

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Reserved	Reserved	Strobe with Horn	Intensity	Intensity

- Default value = 00000110 binary = 06 hex = 6 decimal (bright, strobe with horn).
- Bits 0 and 1 specify the Rear Ditch Lights intensity.

Bit 1	Bit 0	Intensity
0	0	Off
0	1	Dim*
1	0	Bright
1	1	Strobe

- If bit 2 = 1, the Rear Ditch Lights strobe when the horn blows. Note that if the Intensity = Strobe, no change in Rear Ditch Lights behavior will be observed when the horn blows.

* If the Rear Ditch Lights cannot be dimmed, then Dim = Off.

5.7.8.5 CV 55.88.4 Automatic Rear Ditch Lights NFR Configuration

Use this CV to configure how the Automatic Rear Ditch Lights behave when the locomotive is in neutral from reverse.

Default Value: **0**

CV 55.88.4: Automatic Rear Ditch Lights NFR Configuration

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Reserved	Reserved	Strobe with Horn	Intensity	Intensity

- Default value = 00000000 binary = 00 hex = 0 decimal (off).
- Bits 0 and 1 specify the Rear Ditch Lights intensity.

Bit 1	Bit 0	Intensity
0	0	Off
0	1	Dim*
1	0	Bright
1	1	Strobe

- If bit 2 = 1, the Rear Ditch Lights strobe when the horn blows. Note that if the Intensity = Strobe, no change in Rear Ditch Lights behavior will be observed when the horn blows.

* If the Rear Ditch Lights cannot be dimmed, then Dim = Off.

5.7.8.6 CV 55.88.5 Rear Ditch Lights Strobe Hold Time

Use this CV to specify the number of seconds the Rear Ditch Lights continue to strobe after a horn blast ends.

Default Value: **5**

CV 55.88.5: Rear Ditch Lights Strobe Hold Time

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Hold Time	Hold Time	Hold Time	Hold Time	Hold Time

- Default value = 00000101 binary = 05 hex = 5 decimal.
- Valid values are 0…31 seconds.

5.7.8.7 CV 55.88.6 Rear Ditch Lights Strobe Period[115]

For models with Rear Ditch Lights, this CV controls their strobe rate.

Default Value:	**100**

CV 55.88.6: Rear Ditch Lights Strobe Period

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- Valid values are 2…255. Each unit represents 0.01 second. A value of 100 represents 1.00 second. If the value of this CV is 0 or 1, a period of 0.02 second is used.
- The CV value is the time for one complete strobe cycle of both rear ditch lights to complete.
- In Ops mode, with the Rear Ditch Lights strobing, you can observe the strobe rate change as you change the value of CV 55.88.6.

[115] This CV is currently supported only by Q2 firmware for the Quantum Revolution.

5.7.8.8 CV 55.88.10 Rear Ditch Lights Dim Intensity

For models with dimmable Rear Ditch Lights, this CV controls the dim intensity.

Default Value: **Depends on Locomotive**

CV 55.88.10: Rear Ditch Lights Dim Intensity

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	D6	D5	D4	D3	D2	D1	D0

- The default value is dependent on the model.
- Valid values are 0…255, 0 being least intense (off) and 255 being most intense (bright).
- In Ops mode, with the Rear Ditch Lights dimmed, you can observe the Rear Ditch Lights intensity change as you change the value of CV 55.88.10.

5.7.8.9 CV 55.88.12 Rear Ditch Lights Max Intensity[116]

For models with 256 intensity level Rear Ditch Lights, this CV controls its intensity when it's state is "bright" or "strobing".

Default Value:	**255**

CV 55.88.12: Rear Ditch Lights Max Intensity

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- Valid values are 0…255, 0 being least intense (off) and 255 being most intense (bright).
- In Ops mode, with the Rear Ditch Lights state "bright" or "strobing", you can observe the Rear Ditch Lights intensity change as you change the value of CV 55.88.12.

[116] This CV is currently supported only by Q2 firmware for the Quantum Revolution.

5.7.8.10 CV 55.88.SI Rear Ditch Lights Examples

Example 1: I want the automatic rear ditch lights to be bright (not strobing) in all four motive states, NFF, REV and NFR as well as FWD. I want the ditch lights to strobe when the horn blows in both FWD and REV.

Solution: Set CV 55.88.1 and CV 55.88.3 to 00000110 binary = 06 hex = 6 decimal. Set CV 55.88.2 and CV 55.88.4 to 00000010 binary = 02 hex = 2 decimal.

Example2: I want the automatic rear ditch lights to be off in all four motive states. But I want the rear ditch lights to strobe when the horn blows in both FWD and REV.

Solution: Set CV 55.88.1 and CV 55.88.3 to 00000100 binary = 04 hex = 4 decimal. Set CV 55.88.2 and CV 55.88.4 to 0.

Example 3: How will the rear ditch lights behave if I set CV 55.88.0 to 00011111 binary = 1F hex = 31 decimal?

Answer: The automatic rear ditch lights are initially activated and the rear ditch lights intensity is controlled by the CV 55.88.1…4 settings. If the automatic rear ditch lights are deactivated, for example, by pressing FL so that the FL function state is 0, then the Feature 89 function state turns the rear ditch lights on, and the Feature 91 function state makes the rear ditch lights strobe.

Example 4: I want explicit rear ditch lights on/off control at all times. At startup I want the rear ditch lights off until I turn them on with a function key. When the rear ditch lights are on, they should be bright (not strobing).

Solution: First set CV 55.88.0 to 0. Next remove the automatic rear ditch lights feature from multiple automatic lights #1 by setting CV 55.136.0 bit 5 to 0. Finally in CV 53 assign Feature 89 to a function output.

Example 5: Same as example 4, but I want to explicitly dim and strobe the rear ditch lights as well. When I first turn the rear ditch lights on, they should be bright.

Solution: First set CV 55.88.0 to 0. Next remove the automatic rear ditch lights feature from multiple automatic lights #1 by setting CV 55.136.0 bit 5 to 0. Finally in CV 53 assign Feature 89 to a function output, Feature 90 to a second function output, and Feature 91 to a third function output.

Example 6: I want to explicitly strobe the rear ditch lights, but when not strobing the rear ditch lights should be always bright.

Solution: First set CV 55.88.0 to 00000010 binary = 02 hex = 2 decimal. Next remove the Automatic Rear Ditch Lights feature from Multiple Automatic Lights #1 by setting CV 55.136.0 bit 5 to 0. Finally in CV 53 assign Feature 91 to a function output. You do not need to assign Feature 89 to a function output.

Example7: Similar to example 2, I want the automatic rear ditch lights to be off in all four motive states. But I want the rear ditch lights to strobe when the horn blows in FWD only. Further, I want this behavior even if FL is 0.

Solution: First set CV 55.88.0 to 1. Then set CV 55.88.1 to 00000100 binary = 04 hex = 4 decimal. Set CV 55.88.2, CV 55.88.3 and CV 55.88.4 to 0. Finally remove the Automatic Rear Ditch Lights feature from Multiple Automatic Lights #1 by setting CV 55.136.0 bit 5 to 0.

5.7.9 CV 55.92.SI Overhead Beacon Light

One feature can be assigned to function keys to control overhead beacon light operation:

Feature ID	Feature Name	Use
92	OHBL On	Explicitly turn the OHBL On/Off

Explicit Control

The OHBL intensity changes in response to Feature 92 function key presses.

Feature 92 Function State	Intensity
0	Off
1	On

5.7.9.1 CV 55.92.0 OHBL Initial State

Use this CV to specify the startup state function states for the OHBL features.

Default Value: **2**

CV 55.92.0: OHBL Initial State

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Effect	Effect	Reserved	Reserved	Feature 92 Function State	Reserved

- Default value = 00000010 binary = 02 hex = 2 decimal (OHBL on).
- Bit 1 is the initial state of the OHBL On (Feature 92) function.
- Bits 4 and 5 specify the OBHL effect. Three effects are supported:

Bit 5	Bit 4	Effect
0	0	Blinking Light
0	1	Rotary Light
1	0	Strobe Light
1	1	reserved

- A write to this CV in operations mode causes the Feature 92 function state to be immediately set to the new value.
- A start up operation causes the Feature 92 function state to be set to the values in this CV.

5.7.9.2 CV 55.92.6 OHBL Period[117]

For models with a OHBL, this CV controls its blink, revolve, or strobe rate.

Default Value:	**100**

CV 55.92.6: OHBL Period

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- Valid values are 2…255. Each unit represents 0.01 second. A value of 100 represents 1.00 second. If the value of this CV is 0 or 1, a period of 0.02 second is used.
- The CV value is the time for one complete blink, revolve, or strobe cycle of the OHBL to complete.
- In Ops mode, you can observe the blink, revolve, or strobe rate change as you change the value of CV 55.92.6.

[117] This CV is currently supported only by Q2 firmware for the Quantum Revolution.

5.7.9.3 CV 55.92.11 OHBL Min Intensity[118]

For models with a OHBL, this CV controls the minimum brightness of the Rotary Light effect or the bright time of the Strobe Light effect.

Default Value:	**4**

CV 55.92.11: OHBL Min Intensity

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- Valid values are 0…255, 0 being least intense (off) and 255 being most intense (bright). For best results, set CV55.92.11 to a value less than the value of CV55.92.12.
- In Ops mode, with the Rotary Light effect, you can observe the intensity change as you change the value of CV 55.92.11.
- When the Blinking Light effect is selected, this CV is not used.
- When the Strobe Light effect is selected, this CV represents the time the light is in its brightest state. Each unit represents 0.01 second. A value of 4 represents 0.04 second. If the value of this CV is 0 or 1, a bright time of 0.02 second is used. If the value of this CV is greater than the value of CV56.92.6, a bright time ½ the value of CV56.92.6 is used.
- In Ops mode, with the Strobe Light effect, you can observe the bright time change as you change the value of CV 55.92.11.

[118] This CV is currently supported only by Q2 firmware for the Quantum Revolution.

5.7.9.4 CV 55.92.12 OHBL Max Intensity[119]

For models with a 256 intensity level OHBL, this CV controls its brightest intensity.

Default Value:	**255**

CV 55.92.12: OHBL Max Intensity

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- Valid values are 0…255, 0 being least intense (off) and 255 being most intense (bright). For best results, set CV55.92.12 to a value greater than the value of CV55.92.11.
- In Ops mode, you can observe the OHBL intensity change as you change the value of CV 55.92.12.

[119] This CV is currently supported only by Q2 firmware for the Quantum Revolution.

5.7.10 CV 55.96.SI Rear Overhead Beacon Light

One feature can be assigned to function keys to control rear overhead beacon light operation:

Feature ID	Feature Name	Use
96	Rear OHBL On	Explicitly turn the Rear OHBL On/Off

Explicit Control

The Rear OHBL intensity changes in response to Feature 96 function key presses.

Feature 96 Function State	Intensity
0	Off
1	On

5.7.10.1 CV 55.96.0 Rear OHBL Initial State

Use this CV to specify the startup state function states for the Rear OHBL features.

Default Value: **2**

CV 55.96.0: Rear OHBL Initial State

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Effect	Effect	Reserved	Reserved	Feature 96 Function State	Reserved

- Default value = 00000010 binary = 02 hex = 2 decimal (OHBL on).
- Bit 1 is the initial state of the Rear OHBL On (Feature 92) function.
- Bits 4 and 5 specify the Rear OBHL effect. Three effects are supported:

Bit 5	Bit 4	Effect
0	0	Blinking Light
0	1	Rotary Light
1	0	Strobe Light
1	1	reserved

- A write to this CV in operations mode causes the Feature 96 function state to be immediately set to the new value.
- A start up operation causes the Feature 96 function state to be set to the values in this CV.

5.7.10.2 CV 55.96.6 Rear OHBL Period[120]

For models with a Rear OHBL, this CV controls its blink, revolve, or strobe rate.

Default Value:	**100**

CV 55.96.6: Rear OHBL Period

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- Valid values are 2…255. Each unit represents 0.01 second. A value of 100 represents 1.00 second. If the value of this CV is 0 or 1, a period of 0.02 second is used.
- The CV value is the time for one complete blink, revolve, or strobe cycle of the Rear OHBL to complete.
- In Ops mode, you can observe the blink, revolve, or strobe rate change as you change the value of CV 55.96.6.

[120] This CV is currently supported only by Q2 firmware for the Quantum Revolution.

5.7.10.3 CV 55.96.11 Rear OHBL Min Intensity[121]

For models with a Rear OHBL, this CV controls the minimum brightness of the Rotary Light effect or the bright time of the Strobe Light effect.

Default Value:	**4**

CV 55.96.11: Rear OHBL Min Intensity

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- Valid values are 0…255, 0 being least intense (off) and 255 being most intense (bright). For best results, set CV55.96.11 to a value less than the value of CV55.96.12.
- In Ops mode, with the Rotary Light effect, you can observe the intensity change as you change the value of CV 55.96.11.
- When the Blinking Light effect is selected, this CV is not used.
- When the Strobe Light effect is selected, this CV represents the time the light is in its brightest state. Each unit represents 0.01 second. A value of 4 represents 0.04 second. If the value of this CV is 0 or 1, a bright time of 0.02 second is used. If the value of this CV is greater than the value of CV56.96.6, a bright time ½ the value of CV56.96.6 is used.
- In Ops mode, with the Strobe Light effect, you can observe the bright time change as you change the value of CV 55.96.11.

[121] This CV is currently supported only by Q2 firmware for the Quantum Revolution.

5.7.10.4 CV 55.96.12 Rear OHBL Max Intensity[122]

For models with a 256 intensity level Rear OHBL, this CV controls its brightest intensity.

Default Value:	**255**

CV 55.96.12: Rear OHBL Max Intensity

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- Valid values are 0…255, 0 being least intense (off) and 255 being most intense (bright). For best results, set CV55.92.12 to a value greater than the value of CV55.92.11.
- In Ops mode, you can observe the Rear OHBL intensity change as you change the value of CV 55.96.12.

[122] This CV is currently supported only by Q2 firmware for the Quantum Revolution.

5.7.11 CV 55.100.SI Front Number Board Lights

Two features can be assigned to function keys to control front number board lights operation:

Feature ID	Feature Name	Use
100	Automatic Front Number Board Lights Activate	Activate/Deactivate Automatic Control of the Front Number Board Lights
101	Front Number Board Lights On	Explicitly turn the Front Number Board Lights On/Off

The front number board lights intensity (Off, On) can be controlled automatically or explicitly.

Automatic Control

When the Feature 100 function state is 1, automatic control is activated. The front number board lights intensity changes automatically in response to changes to the locomotive's motive state.

The default rules for automatic control are simple: the front number board lights are on regardless of the locomotive's motive state.

The automatic control can be configured in CV 55.100.1.

Feature 100 has precedence over Feature 101. When the Feature 100 function state is 1, the Feature 101 function state is ignored.

Explicit Control

When the Feature 100 function state is 0, automatic control is deactivated. The front number board lights intensity changes in response to Feature 101 function key presses.

Feature 101 Function State	Intensity
0	Off
1	On

Feature 100 has precedence over Feature 101. If the Feature 100 function state changes to 1, because of a Feature 100 function key press or a start up operation, automatic control is re-activated.

5.7.11.1 CV 55.100.0 Front Number Board Lights Initial State

Use this CV to specify the startup state function states for the Front Number Board Lights features.

Default Value: **1**

CV 55.100.0: Front Number Board Lights Initial State

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Feature 101 Function State	Feature 100 Function State

- Default value = 00000001 binary = 01 hex = 1 decimal (Automatic Control Activated).
- Bit 0 is the initial state of the Automatic Front Number Board Lights Activate (Feature 100) function.
- Bit 1 is the initial state of the Front Number Board Lights On (Feature 101) function.
- A write to this CV in operations mode causes the Feature 100 and 101 function states to be immediately set to the new values.
- A start up operation causes the Feature 100 and 101 function states to be set to the values in this CV.

5.7.11.2 CV 55.100.1 Automatic Front Number Board Lights Configuration

Use this CV to configure the Automatic Front Number Board Lights behavior.

Default Value: **85**

CV 55.100.1: Automatic Front Number Board Lights Configuration

NFR		REV		NFF		FWD	
Bit 7	**Bit 6**	**Bit 5**	**Bit 4**	**Bit 3**	**Bit 2**	**Bit 1**	**Bit 0**
Reserved	1 = On	Reserved	1 = On	Reserved	1 = On	Reserved	1 = On

- Default value = 01010101 binary = 55 hex = 85 decimal.
- If bit 0 = 1, the front number board lights are on in FWD.
- If bit 2 = 1, the front number board lights are on in NFF.
- If bit 4 = 1, the front number board lights are on in REV.
- If bit 6 = 1, the front number board lights are on in NFR.

5.7.11.3 CV 55.100.SI Front Number Board Lights Examples

Example 1: I want the automatic front number board lights to be on in FWD and REV, but off in NFF and NFR.

Solution: Set CV 55.100.1 to 00010001 binary = 11 hex = 17 decimal.

Example 2: How will the front number board lights behave if I set CV 55.100.0 to 00000011 binary = 03 hex = 3 decimal?

Answer: The automatic front number board lights are initially activated and the front number board lights intensity is controlled by the CV 55.100.1 settings. If the automatic front number board lights are deactivated, for example, by pressing F11 so that the F11 function state is 0, then the Feature 101 function state turns the front number board lights on.

Example 3: I want explicit front number board lights on/off control at all times. At startup I want the front number board lights off until I turn them on with a function key.

Solution: First set CV 55.100.0 to 0. Next remove the automatic front number board lights feature from multiple automatic lights #2 by setting CV 55.137.0 bit 0 to 0. Finally in CV 53 assign Feature 101 to a function output.

Example 4: I want the front number board lights to be on at all times. But I don't want them to be affected by function key presses.

Solution: First set CV 55.100.0 to 00000010 binary = 02 hex = 2 decimal. Then remove the automatic front number board lights feature from multiple automatic lights #2 by setting CV 55.137.0 bit 0 to 0.

Example 5: I want the front number board lights to be on automatically in FWD and NFF and off automatically in REV and NFR. But I don't want them to be affected by function key presses.

Solution: First set CV 55.100.0 to 00000001 binary = 01 hex = 1 decimal. Then set CV55.100.1 to 00000101 binary = 05 hex = 5 decimal. Finally remove the automatic front number board lights feature from multiple automatic lights #2 by setting CV 55.137.0 bit 0 to 0.

5.7.12 CV 55.102.SI Rear Number Board Lights

Two features can be assigned to function keys to control rear number board lights operation:

Feature ID	Feature Name	Use
102	Automatic Rear Number Board Lights Activate	Activate/Deactivate Automatic Control of the Rear Number Board Lights
103	Rear Number Board Lights On	Explicitly turn the Rear Number Board Lights On/Off

The rear number board lights intensity (Off, On) can be controlled automatically or explicitly.

Automatic Control

When the Feature 102 function state is 1, automatic control is activated. The rear number board lights intensity changes automatically in response to changes to the locomotive's motive state.

The default rules for automatic control are simple: the rear number board lights are on regardless of the locomotive's motive state.

The automatic control can be configured in CV55.102.1.

Feature 102 has precedence over Feature 103. When the Feature 102 function state is 1, the Feature 103 function state is ignored.

Explicit Control

When the Feature 102 function state is 0, automatic control is deactivated. The rear number board lights intensity changes in response to Feature 103 function key presses.

Feature 103 Function State	Intensity
0	Off
1	On

Feature 102 has precedence over Feature 103. If the Feature 102 function state changes to 1, because of a Feature 103 function key press or a start up operation, automatic control is re-activated.

5.7.12.1 CV 55.102.0 Rear Number Board Lights Initial State

Use this CV to specify the startup state function states for the Rear Number Board Lights features.

Default Value: **1**

CV 55.102.0: Rear Number Board Lights Initial State

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Feature 103 Function State	Feature 102 Function State

- Default value = 00000001 binary = 01 hex = 1 decimal (Automatic Control Activated).
- Bit 0 is the initial state of the Automatic Rear Number Board Lights Activate (Feature 102) function.
- Bit 1 is the initial state of the Rear Number Board Lights On (Feature 103) function.
- A write to this CV in operations mode causes the Feature 102 and 103 function states to be immediately set to the new values.
- A start up operation causes the Feature 102 and 103 function states to be set to the values in this CV.

5.7.12.2 CV 55.102.1 Automatic Rear Number Board Lights Configuration

Use this CV to configure the Automatic Rear Number Board Lights behavior.

Default Value: **85**

CV 55.102.1: Automatic Rear Number Board Lights Configuration

NFR		REV		NFF		FWD	
Bit 7	**Bit 6**	**Bit 5**	**Bit 4**	**Bit 3**	**Bit 2**	**Bit 1**	**Bit 0**
Reserved	1 = On	Reserved	1 = On	Reserved	1 = On	Reserved	1 = On

- Default value = 01010101 binary = 55 hex = 85 decimal (On in all motive states).
- If bit 0 = 1, the rear number board lights are on in FWD.
- If bit 2 = 1, the rear number board lights are on in NFF.
- If bit 4 = 1, the rear number board lights are on in REV.
- If bit 6 = 1, the rear number board lights are on in NFR.

5.7.12.3 CV 55.102.SI Rear Number Board Lights Examples

Example 1: I want the automatic rear number board lights to be on in FWD and REV, but off in NFF and NFR.

Solution: Set CV 55.102.1 to 00010001 binary = 11 hex = 17 decimal.

Example 2: How will the rear number board lights behave if I set CV 55.102.0 to 00000011 binary = 03 hex = 3 decimal?

Answer: The automatic rear number board lights are initially activated and the rear number board lights intensity is controlled by the CV 55.102.1 settings. If the automatic rear number board lights are deactivated, for example, by pressing F11 so that the F11 function state is 0, then the Feature 103 function state turns the front number board lights on.

Example 3: I want explicit rear number board lights on/off control at all times. At startup I want the rear number board lights off until I turn them on with a function key.

Solution: First set CV 55.102.0 to 0. Next remove the automatic rear number board lights feature from multiple automatic lights #2 by setting CV 55.137.1 bit 0 to 0. Finally in CV 53 assign Feature 103 to a function output.

5.7.13 CV 55.104.SI Front Marker Lights

Two features can be assigned to function keys to control front marker lights operation:

Feature ID	Feature Name	Use
104	Automatic Front Marker Lights Activate	Activate/Deactivate Automatic Control of the Front Marker Lights
105	Front Marker Lights On	Explicitly turn the Front Marker Lights On/Off

The front marker lights intensity (Off, On) can be controlled automatically or explicitly.

Automatic Control

When the Feature 104 function state is 1, automatic control is activated. The front marker lights intensity changes automatically in response to changes to the locomotive's motive state.

The default rules for automatic control are simple: the front marker lights are on regardless of the locomotive's motive state.

The automatic control can be configured in CV 55.104.1.

Feature 104 has precedence over Feature 105. When the Feature 104 function state is 1, the Feature 105 function state is ignored.

Explicit Control

When the Feature 104 function state is 0, automatic control is deactivated. The front number board lights intensity changes in response to Feature 105 function key presses.

Feature 105 Function State	Intensity
0	Off
1	On

Feature 104 has precedence over Feature 105. If the Feature 104 function state changes to 1, because of a Feature 104 function key press or a start up operation, automatic control is re-activated.

5.7.13.1 CV 55.104.0 Front Marker Lights Initial State

Use this CV to specify the startup state function states for the Front Marker Lights features.

Default Value: **1**

CV 55.104.0: Front Marker Lights Initial State

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Feature 105 Function State	Feature 104 Function State

- Default value = 00000001 binary = 01 hex = 1 decimal (Automatic Control Activated).
- Bit 0 is the initial state of the Automatic Front Marker Lights Activate (Feature 104) function.
- Bit 1 is the initial state of the Front Marker Lights On (Feature 105) function.
- A write to this CV in operations mode causes the Feature 104 and 105 function states to be immediately set to the new values.
- A start up operation causes the Feature 104 and 105 function states to be set to the values in this CV.

5.7.13.2 CV 55.104.1 Automatic Front Marker Lights Configuration

Use this CV to configure the Automatic Front Marker Lights behavior.

Default Value: **85**

CV 55.104.1: Automatic Front Marker Lights Configuration

NFR		REV		NFF		FWD	
Bit 7	**Bit 6**	**Bit 5**	**Bit 4**	**Bit 3**	**Bit 2**	**Bit 1**	**Bit 0**
Reserved	1 = On	Reserved	1 = On	Reserved	1 = On	Reserved	1 = On

- Default value = 01010101 binary = 55 hex = 85 decimal (On in all motive states).
- If bit 0 = 1, the front marker lights are on in FWD.
- If bit 2 = 1, the front marker lights are on in NFF.
- If bit 4 = 1, the front marker lights are on in REV.
- If bit 6 = 1, the front marker lights are on in NFR.

5.7.13.3 CV 55.104.SI Front Marker Lights Examples

Example 1: I want the automatic front marker lights to be on in FWD and REV, but off in NFF and NFR.

Solution: Set CV 55.104.1 to 00010001 binary = 11 hex = 17 decimal.

Example 2: How will the front marker lights behave if I set CV 55.104.0 to 00000011 binary = 03 hex = 3 decimal?

Answer: The automatic front marker lights are initially activated and the front marker lights intensity is controlled by the CV 55.104.1 settings. If the automatic front marker lights are deactivated, for example, by pressing F11 so that the F11 function state is 0, then the Feature 105 function state turns the front marker lights on.

Example 3: I want explicit front marker lights on/off control at all times. At startup I want the front marker lights off until I turn them on with a function key.

Solution: First set CV 55.104.0 to 0. Next remove the automatic front marker lights feature from multiple automatic lights #2 by setting CV 55.137.2 bit 0 to 0. Finally in CV 53 assign Feature 105 to a function output.

5.7.14 CV 55.106.SI Rear Marker Lights

Two features can be assigned to function keys to control rear marker lights operation:

Feature ID	Feature Name	Use
106	Automatic Rear Marker Lights Activate	Activate/Deactivate Automatic Control of the Rear Marker Lights
107	Rear Marker Lights On	Explicitly turn the Rear Marker Lights On/Off

The rear marker lights intensity (Off, On) can be controlled automatically or explicitly.

Automatic Control

When the Feature 106 function state is 1, automatic control is activated. The rear marker lights intensity changes automatically in response to changes to the locomotive's motive state.

The default rules for automatic control are simple: the rear marker lights are on regardless of the locomotive's motive state.

The automatic control can be configured in CV 55.106.1.

Feature 106 has precedence over Feature 107. When the Feature 106 function state is 1, the Feature 107 function state is ignored.

Explicit Control

When the Feature 106 function state is 0, automatic control is deactivated. The front number board lights intensity changes in response to Feature 107 function key presses.

Feature 107 Function State	Intensity
0	Off
1	On

Feature 106 has precedence over Feature 107. If the Feature 106 function state changes to 1, because of a Feature 106 function key press or a start up operation, automatic control is re-activated.

5.7.14.1 CV 55.106.0 Rear Marker Lights Initial State

Use this CV to specify the startup state function states for the Rear Marker Lights features.

Default Value: **1**

CV 55.106.0: Rear Marker Lights Initial State

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Feature 107 Function State	Feature 106 Function State

- Default value = 00000001 binary = 01 hex = 1 decimal (Automatic Control Activated).
- Bit 0 is the initial state of the Automatic Rear Marker Lights Activate (Feature 106) function.
- Bit 1 is the initial state of the Rear Marker Lights On (Feature 107) function.
- A write to this CV in operations mode causes the Feature 106 and 107 function states to be immediately set to the new values.
- A start up operation causes the Feature 106 and 107 function states to be set to the values in this CV.

5.7.14.2 CV 55.106.1 Automatic Rear Marker Lights Configuration

Use this CV to configure the Automatic Rear Marker Lights behavior.

Default Value: **85**

CV 55.106.1: Automatic Rear Marker Lights Configuration

NFR		REV		NFF		FWD	
Bit 7	**Bit 6**	**Bit 5**	**Bit 4**	**Bit 3**	**Bit 2**	**Bit 1**	**Bit 0**
Reserved	1 = On	Reserved	1 = On	Reserved	1 = On	Reserved	1 = On

- Default value = 01010101 binary = 55 hex = 85 decimal ("On" in all motive states).
- If bit 0 = 1, the rear marker lights are on in FWD.
- If bit 2 = 1, the rear marker lights are on in NFF.
- If bit 4 = 1, the rear marker lights are on in REV.
- If bit 6 = 1, the rear marker lights are on in NFR.

5.7.14.3 CV 55.106.SI Rear Marker Lights Examples

Example 1: I want the automatic rear marker lights to be on in FWD and REV, but off in NFF and NFR.

Solution: Set CV 55.106.1 to 00010001 binary = 11 hex = 17 decimal.

Example 2: How will the rear marker lights behave if I set CV 55.106.0 to 00000011 binary = 03 hex = 3 decimal?

Answer: The automatic rear marker lights are initially activated and the rear marker lights intensity is controlled by the CV 55.106.1 settings. If the automatic rear marker lights are deactivated, for example, by pressing F11 so that the F11 function state is 0, then the Feature 107 function state turns the rear marker lights on.

Example 3: I want explicit rear marker lights on/off control at all times. At startup I want the rear marker lights off until I turn them on with a function key.

Solution: First set CV 55.106.0 to 0. Next remove the automatic rear marker lights feature from multiple automatic lights #2 by setting CV 55.137.2 bit 1 to 0. Finally in CV 53 assign Feature 107 to a function output.

5.7.15 CV 55.116.SI Front Cab Lights

Two features can be assigned to function keys to control front cab lights operation:

Feature ID	Feature Name	Use
116	Automatic Front Cab Lights Activate	Activate/Deactivate Automatic Control of the Front Cab Lights
117	Front Cab Lights On	Explicitly turn the Front Cab Lights On/Off

The front cab lights intensity (Off, On) can be controlled automatically or explicitly.

Automatic Control

When the Feature 116 function state is 1, automatic control is activated. The front cab lights intensity changes automatically in response to changes to the locomotive's motive state.

The default rules for front cab light automatic control are:

Forward	Neutral from Forward	Reverse	Neutral from Reverse
Off after 15 seconds	On after 10 seconds	Off after 15 seconds	On after 10 seconds

The automatic control can be configured in CV 55.116.1.

Feature 116 has precedence over Feature 117. When the Feature 116 function state is 1, the Feature 117 function state is ignored.

Explicit Control

When the Feature 116 function state is 0, automatic control is deactivated. The front cab lights intensity changes in response to Feature 117 function key presses.

Feature 117 Function State	Intensity
0	Off
1	On

Feature 116 has precedence over Feature 117. If the Feature 116 function state changes to 1, because of a Feature 116 function key press or a start up operation, automatic control is re-activated.

5.7.15.1 CV 55.116.0 Front Cab Lights Initial State

Use this CV to specify the startup state function states for the Front Cab Lights features.

Default Value: **1**

CV 55.116.0: Front Cab Lights Initial State

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Feature 117 Function State	Feature 116 Function State

- Default value = 00000001 binary = 01 hex = 1 decimal (Automatic Control Activated).
- Bit 0 is the initial state of the Automatic Front Cab Lights Activate (Feature 116) function.
- Bit 1 is the initial state of the Front Cab Lights On (Feature 117) function.
- A write to this CV in operations mode causes the Feature 116 and 117 function states to be immediately set to the new values.
- A start up operation causes the Feature 116 and 117 function states to be set to the values in this CV.

5.7.15.2 CV 55.116.1 Automatic Front Cab Lights Configuration

Use this CV to configure the Automatic Front Cab Lights behavior.

Default Value: **68**

CV 55.116.1: Automatic Front Cab Lights Configuration

NFR		REV		NFF		FWD	
Bit 7	**Bit 6**	**Bit 5**	**Bit 4**	**Bit 3**	**Bit 2**	**Bit 1**	**Bit 0**
Reserved	1 = On	Reserved	1 = On	Reserved	1 = On	Reserved	1 = On

- Default value = 01000100 binary = 44 hex = 68 decimal. (On in NFF and NFR.)
- If bit 0 = 1, the front cab lights are on in FWD.
- If bit 2 = 1, the front cab lights are on in NFF. If the front cab lights were already on in FWD, they remain on in NFF. If they were off in FWD, they come on after 10 seconds.
- If bit 4 = 1, the front cab lights are on in REV.
- If bit 6 = 1, the front cab lights are on in NFR. If the front cab lights were already on in REV, they remain on in NFR. If they were off in REV, they come on after 10 seconds.

5.7.15.3 CV 55.116.SI Front Cab Lights Examples

Example 1: I want the automatic front cab lights to be on in all motive states FWD, NFF, REV and NFR.

Solution: Set CV 55.116.1 to 01010101 binary = 55 hex = 85 decimal.

Example 2: How will the front cab lights behave if I set CV 55.116.0 to 00000011 binary = 03 hex = 3 decimal?

Answer: The automatic front cab lights are initially activated and the front cab lights intensity is controlled by the CV 55.116.1 settings. If the automatic front cab lights are deactivated, for example, by pressing F12 so that the F12 function state is 0, then the Feature 117 function state turns the front cab lights on.

Example 3: I want explicit front cab lights on/off control at all times. At startup I want the front cab lights off until I turn them on with a function key.

Solution: First set CV 55.116.0 to 0. Next remove the automatic front cab lights feature from multiple automatic lights #3 by setting CV 55.138.3 bit 0 to 0. Finally in CV 53 assign Feature 117 to a function output.

5.7.16 CV 55.118.SI Rear Cab Lights

Two features can be assigned to function keys to control rear cab lights operation:

Feature ID	Feature Name	Use
118	Automatic Rear Cab Lights Activate	Activate/Deactivate Automatic Control of the Rear Cab Lights
119	Rear Cab Lights On	Explicitly turn the Rear Cab Lights On/Off

The rear cab lights intensity (Off, On) can be controlled automatically or explicitly.

Automatic Control

When the Feature 118 function state is 1, automatic control is activated. The rear cab lights intensity changes automatically in response to changes to the locomotive's motive state.

The default rules for rear cab light automatic control are:

Forward	Neutral from Forward	Reverse	Neutral from Reverse
Off after 15 seconds	On after 10 seconds	Off after 15 seconds	On after 10 seconds

The automatic control can be configured in CV 55.118.1.

Feature 118 has precedence over Feature 119. When the Feature 118 function state is 1, the Feature 119 function state is ignored.

Explicit Control

When the Feature 118 function state is 0, automatic control is deactivated. The rear cab lights intensity changes in response to Feature 119 function key presses.

Feature 119 Function State	Intensity
0	Off
1	On

Feature 118 has precedence over Feature 119. If the Feature 118 function state changes to 1, because of a Feature 118 function key press or a start up operation, automatic control is re-activated.

5.7.16.1 CV 55.118.0 Rear Cab Lights Initial State

Use this CV to specify the startup state function states for the Rear Cab Lights features.

Default Value: **1**

CV 55.118.0: Rear Cab Lights Initial State

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Feature 119 Function State	Feature 118 Function State

- Default value = 00000001 binary = 01 hex = 1 decimal (Automatic Control Activated).
- Bit 0 is the initial state of the Automatic Rear Cab Lights Activate (Feature 118) function.
- Bit 1 is the initial state of the Rear Cab Lights On (Feature 119) function.
- A write to this CV in operations mode causes the Feature 118 and 119 function states to be immediately set to the new values.
- A start up operation causes the Feature 118 and 119 function states to be set to the values in this CV.

5.7.16.2 CV 55.118.1 Automatic Rear Cab Lights Configuration

Use this CV to configure the Automatic Rear Cab Lights behavior.

Default Value: **68**

CV 55.118.1: Automatic Rear Cab Lights Configuration

NFR		REV		NFF		FWD	
Bit 7	**Bit 6**	**Bit 5**	**Bit 4**	**Bit 3**	**Bit 2**	**Bit 1**	**Bit 0**
Reserved	1 = On	Reserved	1 = On	Reserved	1 = On	Reserved	1 = On

- Default value = 01000100 binary = 44 hex = 68 decimal. (On in NFF and NFR.)
- If bit 0 = 1, the rear cab lights are on in FWD.
- If bit 2 = 1, the rear cab lights are on in NFF. If the rear cab lights were already on in FWD, they remain on in NFF. If they were off in FWD, they come on after 10 seconds.
- If bit 4 = 1, the rear cab lights are on in REV.
- If bit 6 = 1, the rear cab lights are on in NFR. If the rear cab lights were already on in REV, they remain on in NFR. If they were off in REV, they come on after 10 seconds.

5.7.16.3 CV 55.118.SI Rear Cab Lights Examples

Example 1: I want the automatic rear cab lights to be on in all motive states FWD, NFF, REV and NFR.

Solution: Set CV 55.118.1 to 01010101 binary = 55 hex = 85 decimal.

Example 2: How will the rear cab lights behave if I set CV 55.118.0 to 00000011 binary = 03 hex = 3 decimal?

Answer: The automatic rear cab lights are initially activated and the rear cab lights intensity is controlled by the CV 55.118.1 settings. If the automatic rear cab lights are deactivated, for example, by pressing F12 so that the F12 function state is 0, then the Feature 119 function state turns the rear cab lights on.

Example 3: I want explicit rear cab lights on/off control at all times. At startup I want the rear cab lights off until I turn them on with a function key.

Solution: First set CV 55.118.0 to 0. Next remove the automatic rear cab lights feature from multiple automatic lights #3 by setting CV 55.138.3 bit 1 to 0. Finally in CV 53 assign Feature 119 to a function output.

5.7.17 CV 55.136.SI Multiple Automatic Lights #1

The Multiple Automatic Lights #1 feature allows you to activate more than one automatic light feature with a single function key. Select which lights you want to activate in CV 55.136.0 … CV 55.136.2, and assign Feature 136 to a function output in CV 53.

By default, Feature 136 is assigned to outputs 1 and 2 (FL(f) and FL(r)) in CV 53.

By default, Multiple Automatic Lights #1 controls the automatic Headlight, Reverse Light, Front and Rear Mars Lights, Front and Rear Ditch Lights, and Front and Rear Overhead Blinking Lights.

CV 55.136.0 Multiple Automatic Lights #1 Configuration Byte 0

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Rear OHBL (96)	OHBL (92)	Rear Ditch Lights (88)	Ditch Lights (84)	Rear Mars Light (80)	Mars Light (76)	Reverse Light (73)	Headlight (70)

- Default value = 11111111 binary = FF hex = 255 decimal.

CV 55.136.1 Multiple Automatic Lights #1 Configuration Byte 1

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Step Lights (113)	Reserved	Truck Lights (109)	Rear Marker Lights (106)	Front Marker Lights (104)	Rear Number Board Lights (102)	Front Number Board Lights (100)

- Default value = 00000000 binary = 00 hex = 0 decimal.

CV 55.136.2 Multiple Automatic Lights #1 Configuration Byte 2

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Rear Cab Lights (118)	Front Cab Lights (116)

- Default value = 00000000 binary = 00 hex = 0 decimal.

Example: My DCC controller has limited number of function keys and I want to be able to turn all the lights on and off with a single function key, F0. What can I do to accomplish this?

Solution: Set CV 55.136.1 to 255 and set CV 55.136.2 to 255. Since the Multiple Automatic Lights #1 feature is assigned to F0 by default, F0 will now activate or deactivate all the automatic lights. You can also set CV 55.137.1 to 0 and CV 55.138.2 to 0 if you wish, but unless you have F9…F12 on your controller, this should not be necessary.

5.7.18 CV 55.137.SI Multiple Automatic Lights #2

The Multiple Automatic Lights #2 feature allows you to activate more than one automatic light feature with a single function key. Select which lights you want to activate in CV 55.137.0 … CV 55.137.2, and assign Feature 137 to a function output in CV 53.

By default, Feature 137 is assigned to output 13 (F11) in CV 53.

By default, the Multiple Automatic Lights #2 feature controls the automatic Front and Rear Number Board Lights, Front and Rear Marker Lights, Truck Lights, and Step Lights.

CV 55.137.0 Multiple Automatic Lights #2 Configuration Byte 0

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Rear OHBL (96)	OHBL (92)	Rear Ditch Lights (88)	Ditch Lights (84)	Rear Mars Light (80)	Mars Light (76)	Reverse Light (73)	Headlight (70)

- Default value = 00000000 binary = 00 hex = 0 decimal.

CV 55.137.1 Multiple Automatic Lights #2 Configuration Byte 1

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Step Lights (113)	Reserved	Truck Lights (109)	Rear Marker Lights (106)	Front Marker Lights (104)	Rear Number Board Lights (102)	Front Number Board Lights (100)

- Default value = 11111111 binary = FF hex = 255 decimal.

CV 55.137.2 Multiple Automatic Lights #2 Configuration Byte 2

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Rear Cab Lights (118)	Front Cab Lights (116)

- Default value = 00000000 binary = 00 hex = 0 decimal.

5.7.19 CV 55.138.SI Multiple Automatic Lights #3

The Multiple Automatic Lights #3 feature allows you to activate more than one automatic light feature with a single function key. Select which lights you want to activate in CV 55.138.0 … CV 55.138.2, and assign Feature 138 to a function output in CV 53.

By default, Feature 138 is assigned to output 14 (F12) in CV 53.

By default, Multiple Automatic Lights #3 controls the automatic Front and Rear Cab Lights.

CV 55.138.0 Multiple Automatic Lights #3 Configuration Byte 0

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Rear OHBL (96)	OHBL (92)	Rear Ditch Lights (88)	Ditch Lights (84)	Rear Mars Light (80)	Mars Light (76)	Reverse Light (73)	Headlight (70)

- Default value = 00000000 binary = 00 hex = 0 decimal.

CV 55.138.1 Multiple Automatic Lights #3 Configuration Byte 1

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Step Lights (113)	Reserved	Truck Lights (109)	Rear Marker Lights (106)	Front Marker Lights (104)	Rear Number Board Lights (102)	Front Number Board Lights (100)

- Default value = 00000000 binary = 00 hex = 0 decimal.

CV 55.138.2 Multiple Automatic Lights #3 Configuration Byte 2

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Rear Cab Lights (118)	Front Cab Lights (116)

- Default value = 11111111 binary = FF hex = 255 decimal.

5.7.20 CV 55.154.SI Grade Crossing Horn Signal

The Grade Crossing Horn Signal consists of up to 4 horn blasts interspersed with 3 silent periods.

You can specify the duration of each horn blast and the duration of each silent period to the nearest 0.1 second.

The default values for CV55.154.0-6 gives a grade crossing signal consisting of:

An initial horn blast of 3.0 seconds.
A silent period of 1.5 seconds.
A horn blast of 3.0 seconds.
A silent period of 1.5 seconds.
A horn blast of 1.0 second.
A silent period of 1.5 seconds.
A final horn blast of 3.0 seconds.

To play the grade crossing horn signal use CV53 to assign feature 154 to a function key. Then press the function key whenever you want the grade crossing horn signal to play.

CV 55.154.0 Horn Blast 1 Duration

Use this CV to specify the duration of the first horn blast.

Default Value: **30**

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	D6	D5	D4	D3	D2	D1	D0

- Valid values are 0 to 255. If the value of this CV is “0”, the horn blast will not be played.
- The default value of “30” represents 3.0 seconds.

CV 55.154.1 Silent Period 1 Duration

Use this CV to specify the duration of the first silent period.

Default Value: **15**

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	D6	D5	D4	D3	D2	D1	D0

- Valid values are 0 to 255.
- The default value of “15” represents 1.5 seconds.

CV 55.154.2 Horn Blast 2 Duration

Use this CV to specify the duration of the second horn blast.

Default Value: **30**

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	D6	D5	D4	D3	D2	D1	D0

- Valid values are 0 to 255. If the value of this CV is “0”, the horn blast will not be played.
- The default value of “30” represents 3.0 seconds.

CV 55.154.3 Silent Period 2 Duration

Use this CV to specify the duration of the second silent period.

Default Value: **15**

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	D6	D5	D4	D3	D2	D1	D0

- Valid values are 0 to 255.
- The default value of “15” represents 1.5 seconds.

CV 55.154.4 Horn Blast 3 Duration

Use this CV to specify the duration of the third horn blast.

Default Value: **10**

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	D6	D5	D4	D3	D2	D1	D0

- Valid values are 0 to 255. If the value of this CV is “0”, the horn blast will not be played.
- The default value of “10” represents 1.0 seconds.

CV 55.154.5 Silent Period 3 Duration

Use this CV to specify the duration of the third silent period.

Default Value: **15**

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	D6	D5	D4	D3	D2	D1	D0

- Valid values are 0 to 255.
- The default value of “15” represents 1.5 seconds.

CV 55.154.6 Horn Blast 4 Duration

Use this CV to specify the duration of the fourth horn blast.

Default Value: **30**

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	D6	D5	D4	D3	D2	D1	D0

- Valid values are 0 to 255. If the value of this CV is “0”, the horn blast will not be played.
- The default value of “30” represents 3.0 seconds.

Example: To specify a grade crossing signal consisting of two 3.5 second long horn blasts with a 2.0 second silent period in between, set CV55.154.0 to “35”, CV55.154.1 to “20”, CV55.154.2 to “35”, CV55.154.3 to “0”, CV55.154.4 to “0”, CV55.154.5 to “0”, and CV55.154.6 to “0”.

5.7.21 CV 55.178.SI Status Report

By default, Feature 178 is assigned to output 12 (F10) in CV 53.

By default, the Status Report announces the speed in scale MPH or scale KPH in forward and reverse.

5.7.21.1 CV 55.178.0 Status Report Configuration

Use this CV to select the type of information announced in the status report.

Default Value: **1**

CV 55.178.0: Status Report Configuration

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Reserved	Reserved	Scale Miles	Internal Temp	PWM	BEMF	Scale MPH

- Default value = 00000001 binary = 01 hex = 1 decimal.
- If bit 0 = 1, the Scale MPHor Scale KPH is announced in FWD/REV. You can select between SMPH and SKPH in CV56.0.
- If bit 1 = 1, the BEMF is announced in FWD/REV. The spoken BEMF value is preceded by a spoken 'B'.
- If bit 2 = 1, the PWM is announced in FWD/REV. The spoken PWM value is preceded by a spoken 'D'.
- If bit 3 = 1, the Internal Temperature[123] is announced in degrees Celsius. The spoken temperature value is followed by the spoken phrase "degrees C". See CV56.32.0 for temperature calibration information.
- If bit 4 = 1, the Odometer[124] distance traveled is announced in scale miles followed by the word "miles". If you want the distance reported in kilometers, set CV56.0 bit 1 to "1". See CV58.1.x for more information on the odometer feature.

[123] The Internal Temperature feature is currently only available with Q2 O-Scale and G-Scale firmware and with Q2 Quantum Revolution firmware.

[124] The Odometer feature is currently only available with Q2 O-Scale and G-Scale firmware and with Q2 Quantum Revolution firmware.

5.8 CV 56.PI.SI QSI Configuration

Use CV 56 to access Quantum Configuration settings.

CV 56 is implemented as a two-dimensional table of registers. Some rows of this table have only one register and require the use of CV 49 only. Other rows require both CV 49 and CV 50 to select the configuration registers.

5.8.1 CV 56.0: QSI System Configuration (PI = 0)

Use this CV to configure the Quantum system.

Default Value: **0**[125]

CV 56.0: QSI System Configuration Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	0	D5	D4	D3	0	D1	D0

Bit 0 Sounds on Power Up

"0" On power up, the locomotive's sound system will turn on only when a valid DCC Ops Mode packet addressed to the locomotive is received.
"1" On power up, the locomotive's sound system will turn on when any valid DCC Ops Mode packet is received.

Bit 1 Selects between Imperial and Metric Units.

"0" Selects "Imperial Units". The locomotive's speed is reported in scale miles per hour (smph). Under Calibrated Speed Control (see CV 56.4), each speed step increment is equal to 1 smph. "Imperial Units" is the default for models of US prototypes.
"1" Selects "Metric Units". The locomotive's speed is reported in scale kilometers per hour (skph). Under Calibrated Speed Control, each speed step increment is equal to 1 skph. "Metric Units" is the default for models of non-US prototypes.

Bit 3 Selects BEMF synchronized chuff calibration mode[126].

"0" BEMF synchronized chuffs calibration mode "Off" (default).
"1" BEMF synchronized chuffs calibration mode "On". In this mode the locomotive maintains a constant speed at each speed step and, in place of normal chuffing sounds, produces a single short air release sound once per wheel revolution. Cylinder Cocks sounds are turned off to make it easier to hear the air release sound. It is now easy to adjust CV56.13 Chuff Interval Trim to obtain exactly one air release per wheel revolution.

Bit 4 Selects between BEMF synchronized and CAM[127] synchronized chuffs on Steam locomotives.

"0" Synchronize chuffs using BEMF (default).
"1" Synchronize chuffs using a Chuff CAM.

Bit 5 Odometer[128] Mode

[125] The default for models of non-US prototypes is 2, selecting for Metric Units.
[126] The BEMF synchronized chuff calibration is currently available only in Q2 firmware.
[127] Chuff CAMs are currently supported only in Q2 O-Scale and G-Scale locomotives.

"0" BEMF mode (default).
"1" CAM mode.

Bit 7 Reed Switch Disable

"0" Normal Reed Switch operation is in effect (default).
"1" The Reed Switch is ignored for all operations except powerup reset to factory defaults.

All other bits (2,3,6) are ignored.

[128] The Odometer feature is currently only available with Q2 firmware.

5.8.2 CV 56.4: QSI Throttle Mode (PI = 4)

Use this CV to specify how your Quantum Locomotive interprets throttle position.

Default Value:	**1**

CV 56.4: QSI Throttle Mode Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	**0**	**0**	**0**	**0**	**0**	**D1**	**D0**

- Set data in bits 0 and 1 as follows:

  "0" = Standard Throttle Control (STC).
  "1" = Regulated Throttle Control (RTC)[129]
  "2" = Load Compensated BEMF Speed Control (BEMFSC)[130].
  "3" = Calibrated Speed Control (CSC)

- All other bits are reserved and should be set to 0.

- Default is "1", Regulated Throttle Control.

Standard Throttle Control (STC) is the common way to control the power delivered to a locomotive's motor. Under STC, the throttle setting (speed step) explicitly determines the percentage of full power applied to the motor as specified in a speed table. Because the power applied to the motor is constant for a given throttle setting, the speed of the locomotive will change under load, such as climbing grades, pulling a heavy train, binding wheels or gears, and poor track conditions. In addition, the speed of the locomotive will vary as a result of changes in track voltage caused by power pack resistance, track resistance, inconsistent or intermittent pickups, and changes in motor load current.

Calibrated Speed Control (CSC) uses internal motor control electronics to vary the power applied to the motor in an attempt to maintain the same speed regardless of varying load or track voltage conditions. In 128 speed step mode, the locomotive's speed in scale miles per hour (smph) is equal to the throttle setting[131]. Default resolution is in 1-smph increments. If your throttle is set at 35, the locomotive will go 35 smph. In 14 or 28 speed step mode, you need to multiply your throttle settings by 9 and 4.5 respectively to determine the locomotive's speed.

If CV 56.0 bit 1 is set to 1, the locomotive's speed in scale kilometers per hour (skph) is equal to the throttle setting.

Although some prototype locomotives can achieve 128 miles per hour, most were not designed for these speeds. Increasing the speed step above the fastest speed obtainable by your model locomotive will not produce additional speed increase. Your model's top speed is also limited by the track voltage. If your command station cannot supply sufficient voltage, at high speed steps the locomotive will run slower than the throttle indicates.

CSC is a big improvement over STC, but may not work well when locomotives are in Consists or are used as mid train helps or pushers and the locomotives are slightly mismatched in speed calibration. A locomotive that tends to go slightly faster than 35 smph tries to pull the locomotive that tends to go slightly slower than 35 smph up to speed and applies more power to do so. The locomotive that tends to go slightly slower than 35 smph tries to slow the locomotive that tends to go slightly faster than 35 smph and reduces power to do so. The result is that the slightly faster locomotive does all the pulling work while the slightly slower locomotive is dragged along.

Under CSC, the following CV's have no meaning and are not used: CV 2 (V-Start), CV 5 (V-High), CV 25 (Speed Table Selection), CV 66 (Forward Trim), CV 95 (Reverse Trim), and CV 67 – CV 94 (User Defined Speed Tables).

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129 CV56.4 = 1 was the setting for Speed Control, and CV 56.4 = 2 was the setting for RTC on early Quantum 1 factory equipped locomotives.

130 Both CSC and BEMFSC are not available in Q1a or Q2 firmware due to threatened litigation from Mike's Train House (MTH) ®.

131 Because of the way the NMRA has set up speed steps, the actual scale speed is 1 smph less than the speed step (i.e. Speed Step 2 = 1 smph, Speed Step 3 = 2 smph, etc.). Most Command Stations display the throttle setting as 1 less than the speed step (i.e. Speed Step 2 = Throttle Setting 1, Speed Step 3 = Throttle Setting 2, etc.) For those command stations, the throttle setting is equal to scale miles per hour.

Load Compensated BEMF Speed Control (BEMFSC): This is a non-calibrated speed control technique where each speed step corresponds to a specific BEMF target value. The speed control circuitry adjusts the power applied to the motor in order to minimize the difference between the measured BEMF and the target BEMF.

BEMFSC has the same problem with locomotives in a consist as does CSC.

The following CV's are used to determine the BEMF target value: CV 2 (V-Start), CV 5 (V-High), CV 25 (Speed Table Selection), CV 66 (Forward Trim), CV 95 (Reverse Trim), and CV 67 – CV 94 (User Defined Speed Tables).

Regulated Throttle Control (RTC) combines the best of both Standard Throttle Control and Speed Control. The locomotive still uses speed control circuitry to maintain the locomotive's speed but the speed is allowed to increase or decrease slowly in response to loading. When the locomotive encounters an uphill grade, it decreases speed slowly in response to the extra loading. If a locomotive encounters a tight curve or if it has to climb a bad track joint at low speed, it passes through or over these obstacles with little change in speed, just like the prototype. In RTC as in STC, the speed step is a requested power setting, but in RTC the locomotive acts like it weighs thousands of pounds in response to changing loads or layout conditions.

This "intrinsic mass" is not the same as the inertia settings specified in CV 3, CV 4, CV 23, and CV 24, where the locomotive responds to throttle increases and decreases slowly over time. Even with these CV's set to large values, in STC the locomotive would still stop suddenly if it encountered a minor obstacle at slow speeds since there is no Inertial Control circuitry to maintain its motion.

RTC provides an advantage when operating Consists. If the locomotives in a consist are slightly mismatched in speed and experience unequal loading, the RTC firmware in each locomotive responds to automatically equalize the loading.

RTC applies a little more power to the locomotive that tends to run slightly slower, and applies a little less power to the locomotive that tends to run slightly faster. As a result, all the locomotives in the consist tend to work together rather than fight each other.

RTC uses all the standard CV's pertaining to the throttle, including CV 2 (V-Start), CV 5 (V-High), CV 25 (Speed Table Selection), CV 66 (Forward Trim), CV 95 (Reverse Trim), and CV 67 – CV 94 (User Defined Speed Tables).

Example: Select Regulated Throttle Control
1. Set CV 49 to 4. 2. Set CV 56 to 1.

5.8.3 CV 56.5: Regulated Throttle Control (RTC) Minimum Back EMF (PI = 5)

Use this CV to specify the minimum speed under Regulated Throttle Control.

Default Value: **Depends on Locomotive**

CV 56.5: Regulated Throttle Control Minimum BEMF

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	0	0	D4	D3	D2	D1	D0

- For models 100…999, the data range is from 0 to 7. Bits 3…7 are ignored. For models 1000…9999, the data range is 0 to 31. Bits 5…7 are ignored.
- The locomotive will operate at a speed corresponding to this minimum Back EMF until the speed table value corresponding to the throttle position exceeds V-Start at which time the locomotive will gain speed.
- If the value of this CV is 0, the locomotive does not maintain a minimum speed. The locomotive may not move at very low speed steps.
- If your locomotive runs very smoothly under RTC at speed step one, you may consider lowering the RTC Minimum BEMF value. If your locomotive exhibits non-smooth, jerky behavior at speed step one, you may want to increase the RTC Minimum BEMF value until operation is smooth.
- Before setting the minimum Back EMF, make sure that V-Start, CV2, is not affecting the minimum speed at speed step 1. At QSI, we set V-Start to provide minimum speed between speed step 1 and speed step 8[132] in the following way.

Setting CV 2 for Best RTC Minimum Speed Performance at Lower Speed Steps

1. Place locomotive on a level section of track at least a few feet in length.
2. Set V-Start, CV 2, to 0.
3. Set locomotive Throttle Mode to STC in CV 56.4.
4. Set throttle to speed step 8. Unless your track voltage is very high, your locomotive should be stopped.
5. Increase CV2 in increments until the locomotive starts to move.
6. Decrease CV2 until the locomotive stops. Use this value for your CV2 setting.
7. Return to RTC in CV 56.4.

With this CV 2 setting, notice that your locomotive's minimum speed is maintained between speed step 0 and speed step 8. If the locomotive does not increase at speed step 9, you may want to increase CV 2 slightly. See Appendix VI for additional information on operating your locomotive at minimum speed under RTC.

132 Speed step 8 is an arbitrary choice. It maintains a reasonable speed step range that ensures that variations in track voltage settings, locomotive wear-in and others factors do not prevent the locomotive from obtaining a minimum speed at lower speed steps.

5.8.4 CV 56.9: BEMF to Scale MPH Trim[133] (PI = 9)

Use this CV to change the mapping of BEMF to scale MPH.

Default Value: **128**

CV 56.9: BEMF to Scale MPH Trim Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

This CV determines the relationship between the measured BEMF of the motor and the speed of the locomotive in smph. The content of this CV is interpreted as "X / 128", which means a CV value of 128 is equivalent to a Trim Factor of 1.0.

The locomotive announces the speed of the locomotive in Forward or Reverse in a verbal status report. You can trigger the status report by pressing F10. The locomotive's speed can be announced in either scale miles per hour or scale kilometers per hour. To have scale kilometers per hour announced, set CV56.0 bit 1 to "1".

The factory default value for CV56.9 is "128" which represents "1.0". If your locomotive is reporting speeds that are too slow or too fast, you can correct this by increasing or decreasing the value of this CV.

For example, suppose that your locomotive reports that it is moving 30 mph, but that you measure its speed by some other means to be 35 mph. To correct this, set CV56.9 to "149". The "149" is arrived at by the following calculation:

(Measured_Speed / Reported_Speed) * Current_CV56.9
(35 / 30) * 128
1.167 * 128
149

Suppose that now the locomotive reports that it is going 36 mph when it is actually going 35 mph. You can further adjust the mapping by setting CV56.9 to "145" according to the calculation:

(Measured_Speed / Reported_Speed) * Current_CV56.9
(35 / 36) * 149
0.972 * 149
145

5.8.4.1 Calibrating BEMF to SMPH

Here are three ways you can calibrate your locomotive's BEMF to SMPH mapping. Two methods involve measuring your locomotive's actual speed and comparing with the locomotive's reported speed. One method involves comparing the actual distance the locomotive travels with the distance it reports it travels.

Using a Commerical Speedometer

Measure your locomotive's speed using a device similar to one available from
http://www.tonystrains.com/products/tdp-assoc_speed.htm

For best results get your locomotive up to the desired speed and put the locomotive into "Heavy Load" by pressing F9. Under Heavy Load the locomotive acts as if it has enormous inertia and will speed up or slow down very little under varying track conditions.

Have the locomotive report its speed from time to time. You may want to write these numbers down and compute an average.

[133] This CV is currently available only in Q2 firmware.

Adjust CV56.9 as discussed above until the measured speed matches the locomotive's reported speed.

Using a Stopwatch

Use a tape measure to measure a distance on your layout. Mark a start point and a stop point.

For best results get your locomotive up to the desired speed and put the locomotive into "Heavy Load" by pressing F9. Under Heavy Load the locomotive acts as if it has enormous inertia and will speed up or slow down very little under varying track conditions.

Have the locomotive report its speed from time to time. You may want to write these numbers down and compute an average.

When the locomotive passes the start point, start the stopwatch. When the locomotive passes the stop point, stop the stopwatch. Calculate the locomotive's speed as:

Distance_Traveled / Time

Remember to convert your "Distance_Traveled" to miles and the "Time" to hours and multiply by the appropriate scale factor for your model (e.g., "29" for Aristocraft G-Scale).

For example, if the Distance_Traveled is 40 feet 6 inches and the Time is 1 minute 30 seconds, then the SMPH for 1:29 Scale is:

Distance_Traveled / Time
(40.5 feet * 29 * (1 mile / 5280 feet)) / (90 seconds * (1 minute / 60 seconds) * (1 hour / 60 minutes))
(40.5 * 29) / 5280) / (90 / 3600)
(40.5 * 29 * 3600) / (90 * 5280)
8.897 SMPH

The longer your calibration course, the more accurate your calculated speed will be. If you have a small layout, measure the distance for one trip around the layout and run your locomotive 10 times around the layout, starting the stopwatch at the start of the first trip and stopping the stopwatch at the end of the tenth trip.

Adjust CV56.9 as discussed above until your measured speed matches the locomotive's reported speed.

Using the Locomotive's Odometer

Using this method you compare the measured distance traveled against the locomotive's reported distance traveled. When using this method, the Odometer mode must be "BEMF" (CV56.0 bit 5 = '0').

(1) Mark a start point and a stop point on your layout.

(2) Use a tape measure to measure the distance to be traveled through the calibration course. The longer the calibration course, the more accurate the calibration will be. If you have a small layout, measure the distance for one trip around the layout and run your locomotive 10 times around the layout.

(3) Convert the measured length to scale miles and save as "Measured_Scale_Distance". For example, for a G-Scale locomotive (scale 1:29), suppose the measured length around your layout is 60 feet 3¼ inches and the calibration course is 10 times around the layout. Then

Measured_Scale_Distance = (60.27 feet * 10) * (1 mile / 5280 feet) * 29.0
Measured_Scale_Distance = 3.31 scale miles

(4) Move the locomotive to the start point.

(5) Reset the odometer to "0" by writing "0" to CV58.1.0 (see note 3).

(6) Start the locomotive and run it through the calibration course. Stop the locomotive at the stop point.

(7) Have the locomotive report the distance traveled (see notes 1, 2 and 3). Save this value as “Reported_Distance”.

(8) Read out the current trim factor in CV56.9. Save this as “Old_Trim”.

(9) Calculate the new trim factor as shown:

New_Trim = (Measured_Scale_Distance / Reported_Distance) * Old_Trim

(10) Set CV56.9 to the value of “New_Trim”.

(11) Repeat steps 4 thru 10 if desired.

Note 1: To have the locomotive speak out the odometer value in scale miles or scale kilometers, set CV55.178.0 bit 4 to “1”. Then press the F10 key. If you want the odometer value in scale kilometers, set CV56.0 bit 1 to “1”.

Note 2: You can also have the locomotive speak out the odometer value by writing 58 to CV64.1.0. (CV64 is the CV Numeric Verbal Readout).

Set CV49 to “1”
Set CV50 to “0”
Set CV64 to “58”

Note 3: Version 1.1.0.1 and later versions of QuantumCVManager make this easy to do. Just select the Decoder menu item “Odometer…” to display the Odometer dialog box. There is one button for odometer read out and a second button for resetting the odometer.

5.8.5 CV 56.10: Speed Step to Scale MPH Scale Factor (PI = 10)

Use this CV to change the mapping of speed step to scale MPH under Calibrated Speed Control (CSC) .

Default Value: **64**

CV 56.10: Speed Step to Scale MPH Scale Factor Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- This CV determines the relationship between speed steps and smph for CSC. The content of this CV is interpreted as "X / 64", which means a CV value of 64 is equivalent to a Scale Factor of 1.0. Some examples are:

CV 56.10	Scale Factor	Slowest possible speed at Speed Step 2	Fastest possible speed at Speed Step 127.
32 (0x20)	0.5	0.5 smph	63 smph
64 (0x40)	1.0	1 smph	126 smph
128 (0x80)	2.0	2 smph	252 smph

- Change the Scale Factor if you want a more active throttle range for a locomotive under CSC.
- A Scale Factor less than 1.0 makes sense when the top speed of the locomotive is much less than 126 smph. For example, suppose a locomotive has a top speed of 60 smph. With a Scale Factor of 1.0, all speed steps from 61 through 127 will result in a speed of 60 smph. If the Scale Factor is set to 0.5, then the top speed of 60 smph will correspond to speed steps 121 and above.
- A Scale Factor greater than 1.0 make sense when the top speed of the locomotive is much greater than 126 smph. For example, suppose a locomotive has a top speed of 200 smph. With a Scale Factor of 1.0 the locomotive would only go up to 126 smph. If the Scale Factor were set to 2.0, then the top speed of 200 smph would be obtained at speed steps 101 and above.
- The advantage of a Scale Factor of "1.0" is that you easily know the locomotive's speed if you have a command station that displays the current speed step.
- The Scale Factor can also be used to increase the accuracy of locomotive's speed. For example, if your locomotive runs at 34 smph when it should run at 35 smph, you could increase the scale factor slightly to (35/34) * 64 = 66.
- Adjusting the Scale Factor when trying to match locomotives in Consists when all are operating under CSC is another possibility.
- This CV has no effect under Standard Throttle Control, Regulated Throttle Control, or Load Compensated BEMF Speed Control.

5.8.6 CV 56.12: Chuff Interval Scale Factor[134] (PI = 12)

Use this CV to adjust the time between BEMF synchronized chuffs.

Default Value: **32**

CV 56.12: Chuff Interval Scale Factor Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- This byte specifies a scale factor used to determine the amount of time between BEMF synchronized chuffs. This is inversely related to the chuff rate or the number of chuffs per wheel revolution; the larger the scale factor (more time between chuffs), the slower the chuff rate (fewer chuffs per wheel revolution). The content of this CV is interpreted as "X / 32", which means a CV value of 32 is equivalent to a scale factor of 1.0.
- Some examples of different scale factors are:

CV 56.12	Scale Factor	Chuffs Per Wheel Revolution
32 (0x20)	1.0	4
43 (0x2B)	1.3	3
64 (0x40)	2.0	2
128 (0x80)	4.0	1

- To calculate the scale factor for a desired number of chuffs per wheel revolution, use the formula Scale Factor = (4 / N) * 32, where N is the number of chuffs per revolution.
- Use this scale factor to fine-tune the chuff rate. For example, if your locomotive chuffs a little slower than four per revolution, you can decrease the scale factor to 31 (0.97) to slightly increase the number of chuffs per revolution. Or if your locomotive chuffs a little faster than four per revolution, you can increase the scale factor to 33 (1.03) to slightly decrease the number of chuffs per revolution. If your locomotive supports CV56.13, use CV56.13 instead of this CV for fine-tuning the chuff rate.

Note: We recommend that you set the chuff rate at some speed value greater than 2 smph.

134 All QSI equipped steam locomotives since 1-July-04 support CV 56.12 Chuff Interval Scale Factor and it is available on all version 6 software which includes all Life Like and the BLI PRR K4, C&O Texas and all following models.

5.8.6 CV 56.13: Chuff Interval Trim[135] (PI = 13)

Use this CV to adjust the time between BEMF synchronized chuffs.

Default Value: **128**

CV 56.13: Chuff Interval Trim Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- This byte specifies a scale factor used to determine the amount of time between BEMF synchronized chuffs. This is inversely related to the chuff rate or the number of chuffs per wheel revolution; the larger the scale factor (more time between chuffs), the slower the chuff rate (fewer chuffs per wheel revolution). The content of this CV is interpreted as "X / 128", which means a CV value of 128 is equivalent to a scale factor of 1.0.
- Use this scale factor to fine-tune the chuff rate. For example, if your locomotive chuffs a little slower than four per revolution, you can decrease the scale factor to 127 (0.992) to slightly increase the number of chuffs per revolution. Or if your locomotive chuffs a little faster than four per revolution, you can increase the scale factor to 129 (1.008) to slightly decrease the number of chuffs per revolution.
- Set CV56.0 bit 3 to "1" to turn on BEMF synchronized chuff calibration mode to make it easier to adjust the chuff rate.
- If you find that one value of CV56.13 gives good synchronized chuff at one speed, but at another speed a different value of CV56.13 is required, see the Q2Upgrade User Manual for a procedure for calibrating the chuff rate for multiple values of CV56.13.
- This CV is similar to CV56.12 Chuff Interval Scale Factor. The resolution is greater in CV56.13 but the range is less. CV56.12 is a coarse adjustment while CV56.13 is a fine adjustment. In locomotives that support both CV56.12 and CV56.13, both CV's are applied. For example, if CV56.12 is "40" and CV56.13 is "144", then the resulting scale factor applied to the chuff interval is:

  40/32 * 144/128
  1.25 * 1.125
  1.40625

Note: We recommend that you trim the chuff rate at some speed value greater than 2 smph.

135 CV56.13 is currently available only in Q2 firmware.

5.8.7 CV 56.18-21.SI: Quantum PID Parameters

PID parameters are used to control the amount of power applied to the motor of QSI locomotives when operating under Regulated Throttle Control, Calibrated Speed Control, or Load Compensated BEMF Speed Control.

"PID" is an acronym standing for "Proportional, Integral, Differential".

Because model locomotives behave differently at different speeds, we use four different sets of PID parameters within four different speed ranges. Since BEMF is directly proportional to speed, we classify these speed ranges in terms of BEMF ranges.

There are two PID parameters that you can set for each BEMF range. We do not allow changing the Integral term.

5.8.7.1 CV 56.18.SI PID Parameters for Very Slow Speed (PI=18, SI = 0,2)

Default Values:	**Depends on Locomotive**

CV 56.18.0: Proportional Gain for BEMF ≤ 7

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- Use this configuration byte to control Proportional Gain for very slow speeds for: 0 < BEMF ≤ 7. For Q2 firmware, this range is 0 < BEMF <= CV56.5 + 5.
- Valid values are 0 to 255.

CV 56.18.2: Differential Gain for BEMF ≤ 7

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- Use this configuration byte to control Differential Gain for very slow speeds for: 0 < BEMF ≤ 7. For Q2 firmware, this range is 0 < BEMF <= CV56.5 + 5.
- Valid values are 0 to 255.

5.8.7.2 CV 56.19.SI PID Parameters for Slow Speed (PI=19, SI = 0,2)

Default Values: **Depends on Locomotive**

CV 56.19.0: Proportional Gain for: 7 < BEMF ≤ 54.

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- Use this configuration byte to control Proportional Gain for slow speeds for: 7 < BEMF ≤ 54. For Q2 firmware, this range is CV56.5 + 5 < BEMF <= 54.
- Valid values are 0 to 255.

CV 56.19.2: Differential Gain for: 7 < BEMF ≤ 54.

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- Use this configuration byte to control Differential Gain for slow speeds for: 7 < BEMF ≤ 54. For Q2 firmware, this range is CV56.5 + 5 < BEMF <= 54.
- Valid values are 0 to 255.

5.8.7.3 CV 56.20.SI PID Parameters for Medium Speed (PI=20, SI = 0,2)

Default Values: **Depends on Locomotive**

CV 56.20.0: Proportional Gain for: 54 < BEMF ≤ 108.

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- Use this configuration byte to control Proportional Gain for medium speeds for: 54 < BEMF ≤ 108.
- Valid values are 0 to 255.

CV 56.20.2: Differential Gain for: 54 < BEMF ≤ 108.

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- Use this configuration byte to control Differential Gain for medium speeds for: 54 < BEMF ≤ 108.
- Valid values are 0 to 255.

5.8.7.4 CV 56.21.SI PID Parameters for High Speed (PI=21, SI = 0,2)

Default Values: **Depends on Locomotive**

CV 56.21.0: Proportional Gain for: 108 < BEMF.

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- Use this configuration byte to control Proportional Gain for high speeds for: 108 < BEMF.
- Valid values are 0 to 255.

CV 56.21.2: Differential Gain for: 108 < BEMF.

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- Use this configuration byte to control Differential Gain for high speeds for: 108 < BEMF.
- Valid values are 0 to 255.

5.8.7.5 Setting PID Parameters for Quantum Equipped Model Locomotives:

- Make sure your locomotive is in the best possible mechanical condition. RTC can improve the operation of a well-tuned locomotive but it cannot compensate for locomotives that have serious mechanical problems. Set CV 56.4 to “0” to select Standard Throttle Control and operate your model at slow speed over a level piece of straight track at the minimum sustainable speed. Note any gear bind or “catching”. If the locomotive always slows down at the same wheel position, you may need to make mechanical adjustments. With a steam locomotive, look for any mechanical problems with the valve gear. Lubricate all moving joints with appropriate non-corrosive oil and lube the gearbox. Check your electrical pickups and clean the wheels to ensure consistent power to the motor.
- Make sure your test conditions are consistent.
- If you are using a test track or a different layout to set PID parameters, set the DCC track voltage to match the layout you intend to use for normal operation. When we calibrate motor control and throttle CV’s at QSI, we set our track at 16 volts with only the test locomotive on the track and in Neutral.
- Use a flat oval of track that is consistently powered in all sections (i.e. Track voltage should be the same at all locations). Make sure track does not have misaligned track joints or turnouts that can slow the locomotive.
- Reset All CV’s.
- Set Status Report (F10) to both smph and BEMF (set CV 55.178.0 to 3). Speed will be announced first followed by the BEMF value. The BEMF report will be preceded by “B” to distinguish it from the speed report.
- Set minimum BEMF to 3 (set CV 56.5 to 3). This CV specifies the slowest speed the locomotive will travel in RTC.
- Set CV 56.4 to “0” to select STC.
- While in STC, with the throttle set to speed step = 8 (126 speed step range), increase CV 2 until locomotive moves, and then decrease CV 2 until locomotive stops. This will ensure that the low-end speed on your model is not being affected by CV 2 during the PID setting procedure. This will likely be the value of CV 2 you will retain in your model after you have set all your PID parameters.
- Set CV 56.4 to 1 to select RTC and adjust PID parameters:
    1) **Very Slow Speed PID’s:** Set your locomotive to Speed Step 1. Change CV 56.18.0 and CV 56.18.2 to achieve optimal performance.
    2) **Slow Speed PID’s:** Increase your throttle until the Status Report (F10 key) announces a BEMF value between 20 and 56. Change CV 56.19.0 and CV 56.19.2 to achieve optimal performance.
    3) **Medium Speed PID’s:** Increase your throttle until the Status Report (F10 key) announces a BEMF between 56 and 125. Change CV 56.20.0 and CV 56.20.2 to achieve optimal performance.
    4) **High Speed PID’s:** Increase your throttle until the Status Report (F10 key) announces a BEMF greater than 125. Change CV 56.21.0 and CV 56.21.2 to achieve optimal performance
- Transient Response Test**:** Does the locomotive stop smoothly in DCC when the throttle is changed from full throttle to zero throttle quickly? If it overshoots (i.e. slows, speeds up, and then slows again when you lower the throttle quickly and the locomotive slows to its new speed), then PID parameters need to be re-adjusted (see Hints below).
- It is also a good idea to test your PID settings under Analog operation to see if there is any overshoot or surging when the throttle is changed from full to just below V-Start quickly. RTC problems under DC operation almost always appear in DCC, although they can have different characteristics.
- Set New Minimum BEMF: Adjust CV 56.5 for the best possible low speed performance in RTC. If your locomotive runs very smoothly and has good Very Slow Speed PID parameters, the minimum BEMF can be reduced to 1 to achieve the ultimate low-end speed.

5.8.7.6 General Hints for Setting PID Parameters:

Choosing the correct PID parameters is more an art form than a science. Here are some general rules based on our experience that will get you close to the best performance.

1. We usually set the Proportional term (P) between 4 and 16. High values can cause overshooting, or surging when the throttle is changed quickly and low terms can result in poor response time. Higher values of P are generally used at the “Very Slow Speed” and “Slow Speed” BEMF ranges. We have seldom set P above 20 for the “High Speed” range.
2. The Differential term (D) is usually set between 1 and 100 with some notable exceptions as high as 150. The very high values for D are best at the “Very Slow Speed” range, while moderate D values are better at the higher BEMF ranges (10 to 60). High values of D help at slow speeds since this term compensates for rapid changes in speed that can occur from gear binding or minor obstacles such as misaligned track joints. At higher speed, high values of D are less significant since the flywheel momentum will often keep the locomotive moving despite minor gear issues. Too high a value of D will result in surging. This effect is sometimes very subtle. Carefully watch your train for any slight changes in steady-state speed as it moves around that track oval. Too high a Proportional term can also cause steady-state surging.
3. If your locomotive fails the “Transient Response” test, try lowering the Proportional terms and increase the Differential terms for the Slow Speed, Medium Speed and High Speed ranges. Adjustments of the Differential term for Very Low Speed will probably have no effect on transient performance. Try to bring the differential terms closer to the same value for the three top ranges. Do the same for the Proportional term. You will probably have the best luck with the Differential term in adjusting transient performance. The larger the Differential term, the less overshoot or surging the locomotive will do as it slows to it lower speed or stops. However, a large Differential term can result in steady state surging at some speeds. Always go back and check your steady state speed performance after optimizing your transient behavior.

In some cases it is best to ignore all the above. We have seen locomotives that do not fit neatly into the above set of rules. You may want to experiment using your own intuition, knowledge, and methodology. If you do obtain a good set of PID parameters, please let us know or publish for the rest of the railroad community.

5.8.8 CV 56.24.SI: Wheel Diameter[136] (PI = 24,SI = 0,1)

Use this CV to specify the locomotive's wheel diameter to 0.001 of an inch.

Default Value: **NA**

The wheel diameter requires 2 bytes. CV56.24.0 is the least significant byte, and CV56.24.1 is the most significant byte.

CV 56.24.0: Wheel Diameter Low Byte Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

CV 56.24.1: Wheel Diameter High Byte Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

The wheel diameter = low byte + (high byte * 256). This 16 bit number represents the wheel diameter in units of 0.001 inch.

For example, a value of 930 represents a diameter of 0.930 inches. You would set CV56.24.0 to "162" and CV56.24.1 to "3", according to the calculation

Low byte = 930 modulo 256 = 162
High byte = 930 / 256 = 3

This CV is the actual (non-scaled) diameter of the locomotive's wheel as measured using a caliper or ruler.

This CV is used with CV56.25 Locomotive Scale when calculating the distance the locomotive has traveled when the odometer mode = "CAM".

[136] The CAM Odometer feature and this CV is currently only available with Q2 O-Scale and G-Scale firmware.

5.8.9 CV 56.25.SI: Locomotive Scale[137] (PI = 25,SI = 0,1)

Use this CV to specify the locomotive's scale.

Default Value: **NA**

The locomotive scale requires 2 bytes. CV56.25.0 is the least significant byte, and CV56.25.1 is the most significant byte.

CV 56.25.0: Locomotive Scale Low Byte Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

CV 56.25.1: Locomotive Scale High Byte Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

The locomotive scale = low byte + (high byte * 256). This 16 bit number represents the locomotive scale in units of 0.01.

For example, a value of 2900 represents a scale of 29.00. You would set CV56.25.0 to "84" and CV56.25.1 to "11", according to the calculation

Low byte = 2900 modulo 256 = 84
High byte = 2900 / 256 = 11

This CV is used with CV56.24 Wheel Diameter when calculating the distance the locomotive has traveled when the odometer mode = "CAM".

[137] The CAM Odometer feature and this CV is currently only available with Q2 O-Scale and G-Scale firmware.

5.8.10 CV 56.32.0: Room Temperature[138] (PI = 32,SI = 0)

Use this CV to specify the room temperature in degrees Celsius.

Default Value: **26**

CV 56.32.0: Room Temperature Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

When this CV is written a flag is set to read the Internal Temperature at the next powerup and store the value read in long term memory. The stored value is then used to calibrate future Internal Temperature readings.

Note: after setting this CV power off your locomotive and let it set for several minutes to cool down. Then power the locomotive up at which time the Internal Temperature will be calibrated for the room temperature value in CV56.32.0.

The internal temperature can be read out as part of the F10 status report by setting CV55.178.0 bit 3 to “1”.

The locomotive’s firmware continuously monitors the internal temperature. If the internal temperature exceeds 90 degrees Celsius, the horn hoots, and a high temperature motor shutdown is executed. The locomotive stops and the internal temperature is announced every 10 seconds. After a high temperature shutdown occurs, the locomotive must be powered off before normal operation can resume.

[138] The internal temperature feature is currently only available in G-Scale and O-Scale locomotives.

5.8.10 CV 56.128: Reset to Factory Default (PI = 128)

Use this CV to reset CV's to factory default values.

Default Value: **NA**

CV 56.128: Reset to Factory Default Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- Use the Secondary Index to select a range of CV's[139]. Only those CV's in the selected range will be reset; those CV's outside the range are left unchanged.

SI	Reset Operations:
51	Reset CV 51, System Sound Control
52	Reset CV 52, Individual Sounds
53	Reset CV 53, Function Output Mappings
55	Reset CV 55, QSI Feature Configuration
56	Reset CV 56, QSI Configuration
58	Reset CV 58, Odometer
253	Reset all standard NMRA CV's
254	Reset all QSI CV's
255	Reset all CV's

- Write the QSI Manufacturer Number, 113, to CV 56, to execute the reset operation.
- In Operations Mode you will hear "Reset" spoken when the reset operation completes.

Note: "Reset all CV's" may not work correctly in Service Mode on some command stations, because the command station may turn off the track power before the operation is complete. If this happens, reset CV's in separate groups or use Ops Mode Programming.

Example: Reset Quantum decoder to original factory defaults (i.e. Reset all CV's)

1. Set CV 49 to 128.
2. Set CV 50 to 255.
3. Set CV 56 to 113. In Ops Mode, you will hear "Reset" when reset is competed.

Example: Reset the Individual Sound Volumes to factory defaults

1. Set CV 49 to 128.
2. Set CV 50 to 52.
3. Set CV 56 to 113.

[139] Q2 firmware built after 1-June-08 only supports SI = 255.

5.8.11 CV 56.129: Locomotive ID Access (PI = 129)

Default Value: **N/A**

CV 56.129: Locomotive ID Access Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- Use this index with CV 56 if your controller will not allow you to program your locomotive's ID on the main, and programming on the programming track is impossible due to insufficient power from your command station.
- This feature is only supported during Operations Mode programming. It will not work during Service Mode programming.
- Use CV 50 to select between Short Address (CV 50 = 1), High Byte Extended Address (CV 50 = 17) and Low Byte Extended Address (CV 50 = 18).
- When CV 56.129.1 is written, the data byte is written to CV 1. If programming acknowledgement is enabled, you will hear "CV 1 equals <short address>". The data byte must be in the range 1 to 127.
- When CV 56.129.17 is written, the data byte is merely stored in temporary memory. There is no verbal program announcement. The data byte must be in the range of 0xC0 to 0xE7.
- When CV 56.129.18 is written, the two data bytes are written to CV 17 and CV 18, making the locomotive's ID the 2 byte address consisting of the byte written to CV 56.129.17 and the byte written to CV 56.129.18. If you want to verify the full address in Ops Mode, set CV 64 to 17 (or 18) and hear "CV 17 (or 18) equals <long address>".

Note: When programming the Extended Address, you must set CV 56.129.17 before you set CV 56.129.18.

See the CV 17 and CV 18 documentation for description of how to compute and enter the MSB (most significant byte) and the LSB (least significant byte) of your Extended Addresses.

Step-by-Step procedure for entering your short (Primary) address in CV 56.129 in Ops Mode.

1) Find out if your command station accepts Decimal, Binary or Hex[140] inputs for CV entries.
2) Set CV 49 to 129.
3) Set CV 50 to 1.
4) Set CV 56 to your short address. Hear the address spoken back.
5) Change CV 29, bit 5 to "0" to allow operation with your new primary address (see CV 29).

Example: Set your locomotive's ID to the short address "**23**".
1. Set CV 49 to 129 decimal (10000001, 0x81). 2. Set CV 50 to 1. 3. Set CV 56 to 23 decimal (00010111, 0x17). Hear "CV One equals two, three". At this point, the locomotive must be selected as 23 to proceed to step 4.
If you were using the extended addressing to do steps 1-3, then set CV 29 to 34 decimal (00000010, 0x02) for Primary Address Enable and 28/128 Speed Step.
Your locomotive's short ID is now 23 and ready to operate.

140 Hex and Binary numbers are not shown in the following examples. If you require Hex or Binary, use the conversion table in Appendix IX.

Step-by-Step procedure for entering your long (Extended) Address in CV 56.129 in Ops Mode.

1. Find out if your command station accepts Decimal, Binary or Hex inputs for CV entries.
2. Determine the MSB and LSB for your Extended Address (See CV 17/18 instructions and example).
3. Set CV 49 to 129.
4. Set CV 50 to 17.
5. Enter CV 17 (Most Significant Byte) as a Decimal, Binary or Hex number required by your command station. You will hear no verbal response.
6. Next enter CV 18 (Least Significant Byte) as a Decimal, Binary or Hex number. Hear the new full address spoken back.
7. Change CV 29, bit 5 to "1" to allow operation with your new Extended Address (see CV 29).

The following table shows examples for some common train numbers. Just follow the procedure above when entering CV 17 and CV 18.

ID Number	CV 17 (MSB) (Dec)	CV 18 (LSB) (Dec)	CV 17 (MSB) (Hex)	CV 18 (LSB) (Hex)	CV 17 (MSB) (Binary)	CV 18 (LSB) (Binary)
3985	207	145	CF	91	11001111	10010001
3989	207	149	CF	95	11001111	10010101
3708	206	124	CE	7C	11001110	01111100

Example 1: Set your locomotive's long address to "**3985**" (Also see example under CV 17 and 18.)

1. Set CV 49 to 129 decimal (10000001, 0x81).
2. Set CV 50 to 17 decimal (00010001, 0x11).
3. Set CV 56 to 207 decimal (11001111, 0xCF), which is the MSB for your address (you will hear no verbal feedback).
4. Set CV 50 to 18 decimal (00010010, 0x12).
5. Set CV 56 to 145 decimal (10010001, 0x91), which is the LSB for your address. Hear "CV one, seven equals three, nine, eight, five".
6. Set CV 29 to 34 decimal (00100010, 0x22) for Extended Address Enable and 28/128 Speed Step.

Your locomotive's Long ID is now 3985 and ready to operate.

Example 2: Set your locomotive's long address to "**5344**" (See example under CV 17 and 18.)

1. Set CV 49 to 129 decimal (10000001, 0x81).
2. Set CV 50 to 17 decimal (00010001, 0x11).
3. Set CV 56 to 212 decimal (11010100, 0xD4), which is the MSB for your address (you will hear no verbal feedback).
4. Set CV 50 to 18 decimal (00010010, 0x12).
5. Set CV 56 to 224 decimal (11100000, 0xE0), which is the LSB for your address. Hear "CV one, seven equals five, three, four, four".
6. Set CV 29 to 34 decimal (00100010, 0x22) for Extended Address Enable and 28/128 Speed Step.

Your locomotive's Long ID is now 5344 and ready to operate.

5.8.12 CV 56.254: About Quantum Decoder (PI = 254)

Use this CV in Service Mode to read back information about your Quantum locomotive. Use CV 50 to select among the data bytes to retrieve.

Default Value: **NA**

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- Information from this CV is retrieved in Service Mode as a response to VERIFY_BYTE or VERIFY_BIT operations.
- To select which byte of information to retrieve, write data to CV 50 as follows:

  "2" = Retrieve Hardware Profile High Byte.
  "3" = Retrieve Hardware Profile Low Byte.
  "4" = Retrieve Product Model High Byte.
  "5" = Retrieve Product Model Low Byte.
  "6" = Retrieve Firmware Minor Version Number.
  "8" = Retrieve Firmware Build Number.
  "10" = Retrieve Firmware Build Date.Month (1...12).
  "11" = Retrieve Firmware Build Date.Day (1...31).
  "12" = Retrieve Firmware Build Date.Year (02 = 2002).
  "14" = Retrieve Firmware Sound Set Number Low Byte.
  "15" = Retrieve Firmware Sound Set Number High Byte.
  "16" = Retrieve Firmware Last Modified Date.Month (1...12).
  "17" = Retrieve Firmware Last Modified Date.Day (1...31).
  "18" = Retrieve Firmware Last Modified Date.Year (02 = 2002).

- The Firmware Major Version Number can be retrieved from CV 7, Manufacturer's Version Number.

Example: Retrieve the Product Model

1. Write 254 to CV 49.
2. Write 4 to CV 50.
3. Read back CV 56. Save the returned value as H.
4. Write 5 to CV 50.
5. Read back CV 56. Save the returned value as L.
6. The Product Model = (H * 256) + L.

5.8.13 CV 56.255: Play Build Information (PI = 255)

Use this CV in Ops Mode to hear the locomotive speak out information about its firmware.

Default Value: **NA**

CV 56.255: Play Build Information Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	**0**	**0**	**0**	**0**	**D3**	**D1**	**D0**

- Write data to CV 56 as follows:

  "0" = Play Product Model. You will hear the Product Model number (e.g. "300" or "400"). This identifies the locomotive model and the sounds programmed into the software.

  "1" = Play Firmware Version. You will hear three sets of numbers separated by the word "point". The first number is the major version number, the second is the minor version number, and the third is the build number (e.g. "seven point one point five" means Major Version 7, Minor Version 1, Build Number 5).

  "2" = Play Firmware Build Date. This is the date the software was created. You will hear three sets of numbers, each separated by a pause. The first number set is the month, followed by the day of the month, followed by the year (e.g. "six" pause "one five" pause "zero two" means June 15, 2002).

  "3" = Play Hardware Profile number.

  "4" = Play Sound Set number. This number identifies variations on the sounds programmed into the software for a model. The original firmware for a model has Sound Set number "0".

  "5" = Play Firmware Last Modified Date. This is the date the software was modified by a program such as Q2Upgrade. You will hear three sets of numbers, each separated by a pause. The first number set is the month, followed by the day of the month, followed by the year (e.g. "six" pause "one five" pause "zero two" means June 15, 2002).

- Any value other than 0…5 will be ignored and there will be no verbal output.

Note: While the Build Information is playing, all incoming DCC packets are ignored, so wait until the locomotive stops speaking before writing another CV.

Example: Play Firmware Version

7. Write 255 to CV 49.
8. Write 1 to CV 56.
9. Hear Version spoken out: for Major Version 7, Minor Version 1, Build Number 6, you would hear "seven point one point six".

5.9 CV 58.1.SI Odometer[141]

This CV is used to read back or read out the odometer value. It is also used to reset the odometer to 0.

Default Value: **0**

CV 58.1.0: Odometer Byte 0 (Least Significant Byte) Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

CV 58.1.1: Odometer Byte 1 Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

CV 58.1.2: Odometer Byte 2 (Most Significant Byte) Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

All Q2 locomotives have a BEMF driven on-board odometer. The average BEMF reading each second is converted to Scale Miles Per Hour (SMPH) and added to a total stored in long term memory.

Q2 steam locomotives may be equipped with a Chuff CAM. This CAM signals the decoder processor at each of 4 positions of a wheel revolution, thus providing 4 chuffs per revolution. This CAM can also be used as an on-board odometer, given that the diameter of the wheel (CV56.24.0-1) and the locomotive scale (CV56.25.0-1) are known.

BEMF odometer mode is the default. If your locomotive has a Chuff CAM, you can select the CAM odometer mode, by setting CV56.0 bit 5 to “1”.

5.9.1 Odometer Reset

Reset the odometer to “0” by writing “0” to CV58.1.0.

Set CV49 to “1”
Set CV50 to “0”
Set CV58 to “0”

Actually, a write of any value to CV58.1.0, CV58.1.1, or CV58.1.2 will reset the odometer to “0”.

In Ops Mode, the locomotive will respond by saying “Reset”.

The odometer is also reset to “0” when all CV’s are reset to factory default values.

5.9.2 Ops Mode Odometer Read Out

In Ops mode you can have the locomotive verbally read out the odometer value. There are two ways to do this.

(1) Make the odometer reading part of the F10 status report by setting CV55.128.0 bit 4 to “1”. Then whenever you press F10, the locomotive will speak out the odometer value.

(2) Write “58” to CV64.1.0. (CV64 is the CV Numeric Verbal Readout).

[141] The Odometer feature is currently only available with Q2 O-Scale, Q2 G-Scale firmware, and Q2 Quantum Revolution firmware.

Set CV49 to “1”
Set CV50 to “0”
Set CV64 to “58”

By either way, the locomotive speaks out either the scale miles or the scale kilometers traveled, to the nearest 0.01 of a scale mile or scale kilometer. The default is “miles”. If you want the locomotive to speak out the scale kilometers traveled, set CV56.0 bit 1 to “1”.

5.9.3 Service Mode Odometer Read Back

The raw odometer value can be read back in DCC Service Mode. These three CV’s contain the raw odometer value:

CV58.1.0 byte_0 (low order byte)
CV58.1.1 byte_1
CV58.1.2 byte_2 (high order byte)

The raw odometer value is thus

Raw Odometer Value = byte_0 + (byte_1 * 256) + (byte_2 * 256 * 256)

The number of scale miles this represents depends on the Odometer Mode (CV56.0 bit 5).

5.9.4 BEMF Odometer Mode (CV56.0 bit 5 = “0”)

For BEMF odometer mode, the number of scale miles is

Miles = Raw Odometer Value / 3600

From this we can calculate the maximum number of scale miles before the odometer rolls over.

Max_Miles = 16777215 / 3600 = 4660.33

To convert to kilometers, multiply the miles by 1.609.

Kilometers = Miles * 1.609

5.9.5 CAM Odometer Mode (CV56.0 bit 5 = “1”)

For CAM odometer mode, the number of scale miles is

Miles = (Raw Odometer Value * Diameter * Scale * PI) / (4 * 12 * 5280)

The “4” is needed because there are 4 CAM ticks per wheel revolution. The “12” is needed because there are 12 inches per foot. The “5280” is needed because there are 5280 feet per mile. “PI” is 3. 1415926.

Diameter is the Wheel Diameter read back from CV56.24.0 (low byte) and CV56.24.1 (high byte). The diameter is

Diameter = low byte + (high byte * 256)

This number represents the wheel diameter in units of 0.001 inch. For example a value of “1000” represents a diameter of 1.0 inches.

Scale is the Locomotive Scale read back from CV56.25.0 (low byte) and CV56.25.1 (high byte). The scale is

Scale = low byte + (high byte * 256)

This number represents the locomotive scale in units of 0.01. For example, a value of 2900 represents a scale of 29.0.

Thus, we have

Diameter = (CV56.24.0 value + (CV56.24.1 value * 256)) / 1000
Scale = (CV56.25.0 value + (CV56.25.1 value * 256)) / 100
Miles = (Raw Odometer Value * Diameter * Scale * PI) / (4 * 12 * 5280)

The maximum number of scale miles before the odometer rolls over depends on the wheel diameter and the locomotive scale.

Max_Miles = (16777215 * Diameter * Scale * PI) / (4 * 12 * 5280)

To convert to kilometers, multiply the miles by 1.609.

Kilometers = Miles * 1.609

5.10 CV 62 QSI Control[142]

Use this CV to control Programming Verbal Acknowledgement and CV Numeric Readout.

Default Value: **1**

CV 62: QSI Control Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	**0**	**0**	**0**	**0**	**D2**	**0**	**D0**

- Bit 0 = Programming Verbal Acknowledgement Enable

  "0" = disable Programming Verbal Acknowledgement.
  "1" = enable Programming Verbal Acknowledgement.

  If Programming Verbal Acknowledgement is enabled, and you write a value to a CV, the locomotive announces the CV number and its new value. For example, if you set CV 2 to 18, the locomotive will respond with the spoken message "C V two equals one eight".

  If you write a value to a QSI unique CV that uses a Primary Index, the locomotive announces the CV number followed by the Primary Index followed by the new value. For example, if you set CV 52.8 to 9, the locomotive will respond with the spoken message "C V five two point eight equals nine".

  If you write a value to a QSI unique CV that uses a Primary Index and a Secondary index, the locomotive announces the CV number followed by the Primary Index followed by the Secondary Index followed by the new value. For example, if you set CV 53.12.0 to 104, the locomotive will respond with the spoken message "C V five three point one two point zero equals one zero four".

  If you hear a verbal response like "C V three one" but not followed by "equals" and a value, that means that the CV, in this case CV 31, is not implemented.

  Note: During the time a Programming Verbal Acknowledgement is playing, all incoming DCC packets are ignored. If your DCC controller attempts to program several CV's at a time, the second, third, etc. CV's may not be programmed. You should disable Programming Verbal Acknowledgement when using this kind of controller.

- Bit 2 = CV Numeric Readout Control:

  "0" = announce both the CV number and the CV value (default).
  "1" = announce only the CV value.

  This bit is used to specify whether or not the decoder announces the CV number as well as the CV value for a CV64 operation.

  For example, suppose the value of CV2 is "32". If this bit were "0", and you wrote "2" to CV64, you would hear "C V two equals three two". If this bit were "1", you would hear "three two".

Programming Verbal Acknowledgement and CV Numeric Readout are available only during Ops Mode. In Service Mode, there is not sufficient track power to run the Quantum Sound System.

The overall System Volume determines the volume for these verbal responses. If you cannot hear the Ops Mode verbal responses, you will need to turn up the System Volume (see CV 51.0).

If you cannot hear verbal responses during Ops Mode programming, check to see if you have activated the Mute feature.

142 Write bit operation is supported for CV 62.

Example: To Disable Programming Verbal Acknowledgement
1. Set CV 62 to 0.

Example: To Disable Programming Verbal Acknowledgement and specify CV Numeric Readout of the CV Value only.
1. Set CV 62 to 4.

5.11 CV 64 CV Numeric Verbal Readout (Verbal CV Inquiry)

Use this CV to hear the locomotive speak the value of any CV as a decimal number. This works only in Operations Mode.

Default Value: **NA**

CV 64: Numeric Verbal Readout Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- To hear the locomotive speak the value of a Standard NMRA CV:
    1) Write the number of the CV to CV 64.
    2) The decoder will respond something like “C V three five equals four”.
    3) If the decoder responds something like “C V three one” but not followed by “equals” and a value, that means that the CV, in this case CV 31, is not implemented.
- To hear the locomotive speak the value of a QSI Unique CV:
    1) Determine the Primary Index for the value you want to know. If a Primary Index is required, write the Primary Index number to CV 49.
    2) Determine the Secondary Index for the value you want to know. If a Secondary Index is required, write the Secondary Index number to CV 50.
    3) Write the number of the QSI CV to CV 64.
    4) The decoder will respond something like “C V five two point eight equals five”.
    5) If the decoder responds something like “C V five two point 1” but does not follow this with “equals and a value, this means that the CV, in this case CV 52.1, is not implemented.”
- Writing either 17 or 18 to CV 64 will produce a verbal response indicating the full value of the Extended Address.
- The overall System Volume determines the volume for these verbal responses. If you cannot hear the Ops Mode verbal responses, you will need to turn up the System Volume (see CV 51.0).
- If you cannot hear verbal responses during Ops Mode programming, check to see if you have activated the Mute feature.
- CV62 bit 2 controls whether decoder speaks out the CV number as well as the CV value.

Note: While the Verbal Readout is playing, all incoming DCC packets are ignored, so wait until the locomotive stops speaking before writing another CV.

Example: Hear the current setting for CV 2 V-Start.

1. Write 2 to CV 64.
2. Hear the value spoken out: if the value of CV 2 were “32”, you would hear “C V two equals three two”.

Example: Hear the current setting of the bell volume.

1. Set CV 49 to 8. (The Individual Sound Identifier for Bell is “8”; see table in CV 52)
2. Set CV 64 to 52.
3. Hear the Bell volume spoken out: if the bell volume were 13, you would hear “C V five two point eight equals one three”.

6 CV's 66-95: NMRA Standard CV's

This section describes in detail additional NMRA standard CV's supported by Quantum locomotives.

6.1 CV 66 Forward Trim

Forward Trim specifies a scale factor by which a voltage drive level should be multiplied when the controller is driving the unit in the Forward Direction.

Default Value: **128**

CV 66: Forward Trim Register

Bit 7 (MSB)	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0 (LSB)
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- The Forward Trim factor preserves the same curve shape as specified in the speed table but allows a simple multiplying factor to scale it larger or smaller for "trimming" its speed behavior in Forward. This allows making fine adjustments to match the speed of other locomotives, and to match the locomotive's Reverse speed characteristics.
- The multiplying scale factor is n/128 where "n", the Forward Trim Factor, can be any number entered into CV 66 from 0 to 255. If n = 128, then multiplying scale factor is 1 resulting in no change to the speed curve.
- If Forward Trim Factor is "0", then Forward Trim is not implemented.
- If Forward Trim Factor is between 1 and 128 than the voltage applied to the motor is decreased by a multiplying factor that varies from .00775 to .99225.
- If Forward Trim Factor is between 130 and 255 than the voltage applied to the motor is increased by a multiplying factor that varies from 1.0078 to 1.977.
- CV 66 only applies if the speed tables are activated in CV 29 by setting bit 4 = 1.

6.2 CV 67-94 User Defined Speed Table

Use CV's 67–94 to specify a custom speed table that is suitable for your locomotive.

CV 67-94: User Defined Speed Registers

Bit 7 (MSB)	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0 (LSB)
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- The speed table consists of 28 data points for each of 28 speed steps. A value of 255 means full voltage applied to the motor while a value of 0 means no additional voltage applied to the motor over the V-Start voltage (CV 2).
- If you select 14 speed steps, every other data value is used. If you select 128 speed steps, extra points will be interpolated between each of the 28 data points to provide a smooth curve consisting of 255 points.
- The User Defined Speed Table must be enabled by setting CV 29 bit 5 to 1 and CV 25 bit 1 to 0 or 1.
- Default Values:

CV #	Speed Step	Default Value
CV 67	Speed Step 1	0
CV 68	Speed Step 2	9
CV 69	Speed Step 3	18
CV 70	Speed Step 4	28
CV 71	Speed Step 5	37
CV 72	Speed Step 6	47
CV 73	Speed Step 7	56
CV 74	Speed Step 8	66
CV 75	Speed Step 9	75
CV 76	Speed Step 10	85
CV 77	Speed Step 11	94
CV 78	Speed Step 12	103
CV 79	Speed Step 13	113
CV 80	Speed Step 14	122
CV 81	Speed Step 15	132
CV 82	Speed Step 16	141
CV 83	Speed Step 17	151
CV 84	Speed Step 18	160
CV 85	Speed Step 19	170
CV 86	Speed Step 20	179
CV 87	Speed Step 21	188
CV 88	Speed Step 22	198
CV 89	Speed Step 23	207
CV 90	Speed Step 24	217
CV 91	Speed Step 25	226
CV 92	Speed Step 26	236
CV 93	Speed Step 27	245
CV 94	Speed Step 28	255

6.3 CV 95 Reverse Trim

Reverse Trim specifies a scale factor by which a voltage drive level should be multiplied when the controller is driving the unit in the Reverse direction.

Default Value: **128**

CV 95: Reverse Trim Registers

Bit 7 (MSB)	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0 (LSB)
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

- The Reverse Trim factor preserves the same curve shape as specified in the speed table but allows a simple multiplying factor to scale it larger or smaller for "trimming" its speed behavior in Reverse. This allows making fine adjustments to match the speed of other locomotives, and to match the locomotive's Forward speed characteristics.
- The multiplying scale factor is n/128 where "n", the Reverse Trim Factor, can be any number entered into CV 66 from 0 to 255.
- If the Reverse Trim Factor is "0", then Reverse Trim is not implemented.
- If the Reverse Trim Factor is between 1 and 128 than the voltage applied to the motor is decreased by a multiplying factor that varies from .00775 to .99225.
- If the Reverse Trim Factor is between 130 and 255 than the voltage applied to the motor is increased by a multiplying factor that varies from 1.0078 to 1.977.
- CV 95 only applies if the speed tables are activated in CV 29 by setting bit 4 = 1.

Appendix I

Recommended DCC Command Stations

Command Station	Recommended	Will Support Service Mode w/ Quantum	Comments[143]
NCE ™	Yes	Yes (See Comments)	Horn and Bell buttons are available but bell button assigned to F3 (see QSI CV 37 example). Newer NCEs apparently support programming track but older command stations do not. Programming on the main is easy and straightforward. NCE currently only supports F0-F8.
Wangrow ™	Yes	No	Horn and Bell buttons are available but bell button assigned to F3 (see QSI CV 37 example). No Service Mode but programming on the main is easy and straightforward.
Digitrax ™	Yes	Yes	F0 = Lights, F1 = Bell, F2 = Horn. DT300 will operate in Service mode but will not read back value. Long address is automated with the DT300 and DT400 throttles, which properly writes CVs 18, 17, and 29. Click to the 4-digit mode, set address, and answer yes to the enable 4 digit address prompt. It also automatically resets CV 29 if you return to 2-digit address. An exception is the obsolete DT100 throttle, which will only program Quantum decoders in Ops Mode. Use QSI CV 56.129 to program either CV 1 or CV 17/18. Note that the DT100 only programs in hex, except for addresses, which are in decimal. This makes it easy to enter address in Ops mode. We have qualified the following Digitrax systems with Quantum decoders (all support F0-F12): Super Chief with DT400 Zephyr with DT400 DCS100 with DT400 Chief with DT400 See Digitrax for more information on QSI compatibility at www.digitrax.com.
MRC ™	Yes	No	MRC does not provide a separate programming function. All programming is done in Ops mode with no acknowledgement feedback. A resistor is included to limit current for a Programming Track, which may limit the current below the allowable level for Quantum decoder programming. For the Quantum system, the resistor may be left out. For other decodes, the user should follow the MRC instructions.
Lenz ™ LZ100, LV200, LZV100	Yes	Yes (See Comments)	F0 = Lights, F1 = Bell, F2 = Horn. Lenz will program in Service mode providing that a suitable resistor is added in series to the Programming Track (LV100 requires 20 ohms and LV200 requires 10 ohms). Note that CV 1, 17 and 18

143 Many comments and opinions regarding operation with different command stations are the result of user's letters to QSI or comments on various railroad web forums. QSI is not responsible for the accuracy of these comments, which are included here only as a starting point for the customer to verify to his own satisfaction the compatibility of these products for use with the QSI Quantum System.

			cannot be programmed on the main in the standard way (see QSI CV 56.129 for alternative way to program ID numbers). Newer Lenz does support F0-F12 Function Keys.
Atlas ™	Yes	Yes (See Comments)	Early models of the Atlas command station had some problems with programming. Reports from Atlas on their recent versions indicate no problems. Limited number of function keys available.
CVP ™	Yes	Yes	EZ DCC. Works with wireless hand held throttle as well as standard command station.
Zimo ™	Yes	Yes	All products work with Quantum decoders.

Appendix II A

Programming a Long Address on Digitrax

Select the Loco's Short Address (Usually 3)

- Press “Loco” then “3” then “Enter”.

Program "On the main" the new Long Address.

- Press “PROG” until “Po” and the Loco's address is shown on the LCD.
- Press right turn knob down until it reads “ad4 = ???”
- Type in desired four digit address and press “Enter”. Loco verbally responds with “CV 18 = XXXX” where XXXX is the four digit address.

Once the long address is programmed, you must enable the locomotive to use it.

Enable the Long Address.

- Next, press the right turn knob until it reads “ad2 = 000”
- Scroll with left knob until you get to “029 = ???”; turn right knob until readout = “029 = 034”; press Enter, locomotive says “CV 29 = 34”.
- Press “Exit” to leave program mode.

Select Loco with the new Long Address.

- Press “LOCO” and enter new long address to run locomotive.

Returning to the Short Address

Select the Loco's Long Address (The value you programmed above)

- Press “Loco” then the Long Address then “Enter”.

Program "On the main" to Enable the Short Address.

- Press “PROG” until “Po” and the Loco's address is shown on the LCD.
- Scroll with left knob until you get “CV29 = ???”; scroll with right knob until you get “029 = 002”; press Enter; locomotive verbally responds with “CV 29 = 2”.
- Press “Exit” to leave program mode.

Select Loco with the Short Address.

- Press “LOCO” and enter Short Address to run locomotive.

Appendix II B

Programming a Long Address on North Coast Engineering (NCE)

Select the Loco's Short Address (Usually 3)

- Press “Loco” then “3” then “ENTER”.

Program "On the main" the new Long Address.

- Press the “Program” button. Display reads “Program on Main”.
- Press “ENTER”.
- Display shows current “003” I.D. on the display…..Press “ENTER”
- Press 1 for Address. Display shows “Set ADDR”
- Press “1” to set Long Address.
- Enter four digit address. Press “Enter” Hear “CV 18 equals XXXX” where XXXX is the four digit address you entered.
- You are now back in Run Mode. Select loco 3. Press “ENTER”.
- Once the long address is programmed, you must enable the locomotive to use it.

Enable the Long Address.

- Press the “Program” button. Display reads “Program on Main”.
- Press “ENTER”.
- Display shows current 003 I.D. on the display. Press “ENTER”
- Press “3” for Configuration. Display shows “ENTER=NORM 1=REV”.
- Progress through and set each variable until you reach “ADDRESS?”.
- Enter “1” for “LONG” address. This enables using the long address.
- Leave Ops Mode Programming by pressing the red “Emergency Stop” button.
- Select locomotives long address and operate.

You are now out of program mode and have completed "the Long Address" sequence.

Returning to the Short Address

Select the Loco's Long Address (The value you programmed above)

- Press “Loco” then enter the Loco’s Long Address (The value you programmed above) then press “Enter”.

Program "On the main" to Enable the Short Address.

- Press the “Program” button. Display reads “Program on Main”.
- Press “ENTER”
- Display shows current Long Address I.D. on the display. Press “Enter”

- Press “3” for Configuration. Display shows “ENTER=NORM 1=REV”.
- Progress through each variable until you reach “ADDRESS?”.
- Press “ENTER” for “SHORT” address. This enables using the short address.
- Leave Ops Mode Programming by pressing the red “Emergency Stop” button.
- Select locomotives short address and operate.

The above procedure was evaluated with an upgraded[144] NCE POWER PRO series of DCC command stations. If the above procedure does not work properly, contact NCE to see if they can upgrade your software.

144 NCE Software Version 1.3, December, 21, 2004.

Appendix III

DCC Troubleshooting

Operations Mode

My headlight does come on when I start my locomotive but mysteriously goes off whenever I blow the horn or turn on the bell. Also, if I try to turn off the headlight, it sometimes requires two pressings for the F0 or FL key.	Pressing the horn or toggling the bell will cause your command station to send out a Function Group One command, which contains the lighting information. Not all command stations automatically send this information unless FL, F1, F2, F3 or F4 is pressed. Regarding turning off the lighting with the F0 key, the state for the light may already be off at the base station but not sent. When you press the F0 key, it toggles the lights on and sends that command and hence the lights stay on. It takes a second press of the F0 key to send another command to turn off the lights.
My brakes,, bell, air release, or other sounds come on sometimes for no apparent reason while operating my locomotive.	See above. Some functions may already be turned on but not sent. When you request any function, the entire function group that contains that function will be sent and this may trigger other features already enabled within that group. Hence, you might request the light be turned on and hear squealing brakes or the bell turn on or off. If your base station display shows the toggled condition for each of the function keys, you can determine which feature will turn on or off when a Function Group One or a Function Group Two is sent.
My locomotive makes no sounds except an air release when power is applied and will not operate.	You have your locomotive in Shut Down. Double press the F6 Start-Up key to start your locomotive.
My locomotive runs but makes no sounds.	Your have Mute on or have turned down your System Volume or individual feature sound volumes. You may have a broken wire to the speakers or a faulty speaker.
When I turn up my throttle to higher values, the locomotive does not speed up but instead, the directional lighting comes on.	Your locomotive is set for 14 speed steps but your base station is set for 28 or 128.
When I turn on my lighting system with the F0 or FL Key, the locomotive speeds up at low throttle settings.	Your locomotive is set for 28 or 128 speed steps but your base station is set for 14.
Sometimes my locomotive slows down when I blow the whistle or horn, particularly at high volume levels.	The Quantum Sound system takes additional power to blow the whistle or horn and this loads your power pack. This can lower the voltage on the track and your locomotive will slow down. Purchase a power pack with good line regulation to prevent this problem.
In Speed Control Mode, there are no speed changes above certain throttle settings.	The top speed of your locomotive is dependent on the gear ratio, load on the locomotive and the available voltage applied to the track. Asking the locomotive to go faster results in no change. (See CV 56.10, BEMF to SMPH Scale Factor to change throttle range).
Under speed control, I do not get 1 scale mile per hour (smph); I get a larger number about 5 to 10 smph.	Check your speed step setting on your base station. To get 1 smph you need to be in 128 speed steps.
In Standard Throttle Control Mode, there are no speed changes above a certain throttle settings.	Try a different speed curve or define your own to provide full range of throttle motion.
My locomotive operates with no problem in DCC, but does not operate at all under Analog control.	Make sure Analog operation is enabled. CV 29 bit 2 must be set to 1.
My Lionel Gas Turbine will not operate over 25 smph under RTC or Speed Control.	This is correct for diesel operation. This is an internal limit on top speed when the locomotive is under diesel operation. The prototype would not travel over 25 mph under diesel power. Switch to turbine operation to gain higher speeds.
F8 key on Digitrax does not mute the locomotive.	The Digitrax DT400 model we examined behaves incorrectly when the F8 key is pressed sending 1010DDDD instead of 1011DDDD. Ask Digitrax for a Software Upgrade.
The F7 Key does not apply brakes.	Make sure your throttle is at speed step zero before applying brakes. Also, earlier Quantum systems only required that the F7 be pressed to trigger the brakes. Later Quantum decoders required F7 to be on (1) before brakes will apply. If F7 was already on when the throttle was turned down it will not automatically apply brakes. Pressing it would turn F7 off (0) so a second pressing was required to turn in on.

When I set CV 17 and 18, the Extended Address, I must explicitly set CV29 bit 6 to 1 before the Extended Address is effective. With non-QSI decoders, I don't have to do this. Why isn't it automatic with QSI decoders? ,	If CV 62 bit 0 is "1", which enables Programming Verbal Acknowledgement, then your QSI decoder speaks out "C V 1 7 equals x x x x" when you program the extended address. During the time the acknowledgement is being spoken, all incoming DCC packets are discarded. If your controller attempts to program CV29 during this time, the packet for CV29 is discarded by the decoder. Set CV 62 bit 0 to 0, and your QSI decoder will not discard the CV 29 packet.

Service Mode Operation using the Program Track

My Quantum equipped locomotive will not program in Service Mode with my command station.	Some command stations do not provide sufficient current to power the Quantum system. If you are using a command station that has selectable track voltage for the different scales try using the O'Scale or G'Gauge alternative. If this does not work, use Ops Mode programming. You can also purchase from Tony's Train Exchange®[145], a simple, inexpensive power booster (PowerPak™ by DCC Specialties) that will allow you to program on the program track with any DCC command station.
Occasionally, when programming a CV, the reported value is off by one digit.	This is a timing issue with some command stations. Either program in Ops Mode or consider using a PowerPak from DCC Specialties.
When I try to do a complete reset of all CV's using CV 56.128.255 in Program Mode, not all of the CV's reset to factory values.	Resetting all CV's takes considerable time. Some command stations only allow a fixed short amount of time to power the programming track after a command is sent. When you ask for a complete reset, not all of the CV's will be reset if the power shuts down part way through the procedure. We recommend doing a full reset in Ops mode. Or you can do individual reset operations such as "all NMRA CV reset", and "all QSI CV reset", etc. until you have all groups of CV's reset to factory defaults.

145 Tony's Train Exchange; 1-800-978-3427; info@ttx-dcc.com .

Appendix IV

Recommended Reading:

Ames, S., Friberg, R., and Loizeaux, E. *Digital Command Control*. Allt om Hobby 1998

Ireland, Zana (Editor In Chief), *The Digitrax Big Book of DCC*, Digitrax, 1999.

Strang, Lionel, *DCC Made Easy*, Kalmbach Publishing 2003

Polsgrove, Mike,DCC Projects & Applications, Kalmbach Publishing, 2006.

Appendix V

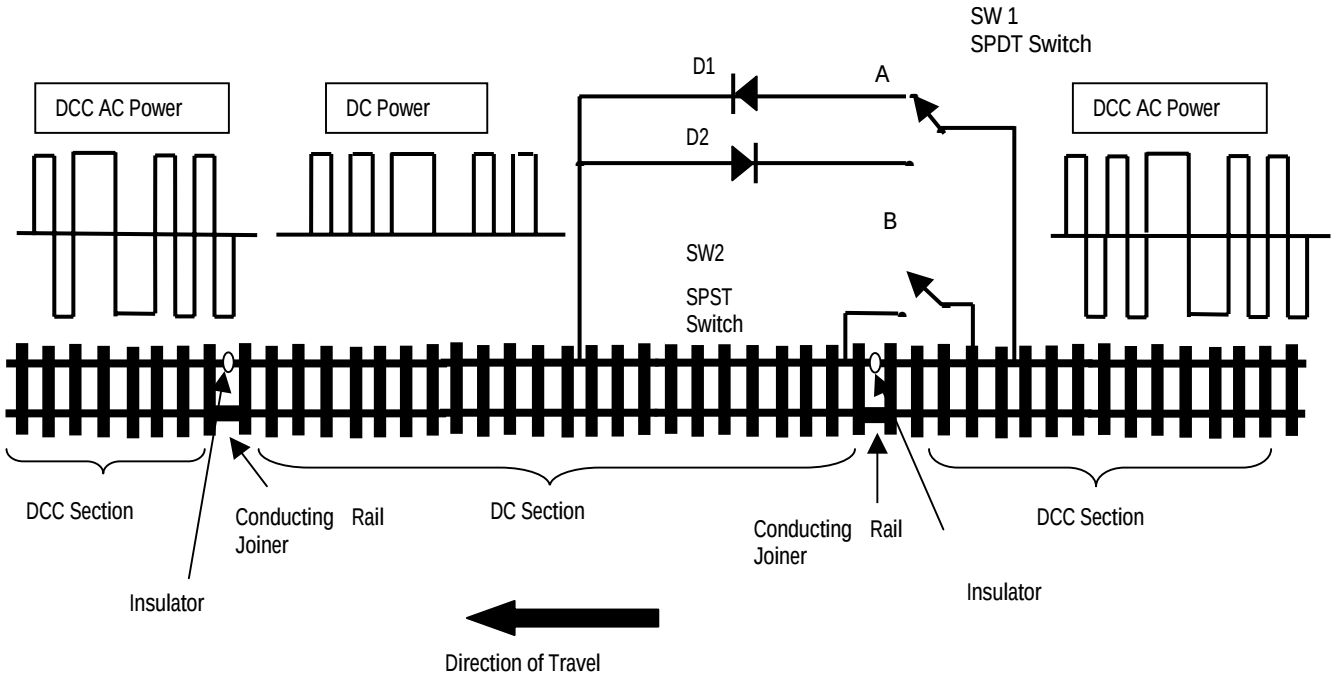
Application Notes:

Using DC Power Conversion for Block Signal Control

CV 29, Bit 2 =1. Applications for DC Power Conversion: Block Signal Control

DCC Power Conversion as described under CV 29, bit 2, was implemented into Quantum decoders in a way that allows for simple block signal control. Using DC power conversion allows the operator to enable a red signal light to stop a train smoothly, using its internal momentum settings, without having to use the throttle. If Bit 2=1 for CV 29, a DCC controlled locomotive will automatically engage DC Power Conversion when it enters a section of track that is powered with standard DC. If the polarity would normally power the analog locomotive in the direction it is going when it enters the DC section, the locomotive will continue through the DC block at the same speed. If the polarity would normally power the locomotive in the Reverse direction, the locomotive will smoothly come to a stop in the DC section.

The diagram below shows a DCC section connected to a DC section of track. The DC section is powered from the DCC power signal rather than from a separate power supply or battery. For this application, it is only necessary to insulate the one rail as shown by the two insulated rail joiners at either end of the DC section; the other rail is electrically connected to the DCC section by conductive rail joiners.



When switch 2 (SW 2) is open, the DCC signal is half-wave rectified by diodes D1 or D2 to produce a positive DC signal to the DC section when Switch 1 is at position A or a negative DC signal when Switch 1 is at position B. If Switch 2 is closed, the DCC signal is connected directly to the DC section and D1 and D2 have no effect on applying DC power to the DC section.

If DC power conversion is enabled in CV 29 (bit 2 = 1) and SW 2 is open, the polarity on the DC section can be used to stop the Quantum equipped locomotive or let it precede, depending on the position of SW 1. If the locomotive is entering the DC section from the right, and SW 1 is set to A, the locomotive will continue at its current speed setting through the DC section. The locomotive, of course, will not respond to DCC signals until it leaves the DC section and reenters the DCC powered section at the far left. On the other hand, if SW 1 is set to B, the polarity on the DC section is opposite the locomotive's direction and the locomotive will slow to a stop at its DCC momentum setting. If the polarity is reversed again to be consistent with the locomotive's direction, the locomotive will accelerate at its current DCC momentum setting to leave the DC section. Alternately, SW 2 could have been closed to cause DCC signals to be applied to the stopped locomotive, which would also have caused the locomotive to accelerate at its current DCC momentum value to its DCC speed setting.

Since the DC portion is powered from the DCC signal, there are no short circuit problems between the DCC powered section and the DC section as the locomotive wheels pass over the track insulators. In addition, since the Quantum locomotive is equipped with large filter capacitors, the reduced power of half-wave rectification will not affect the power available to operate the locomotive so there is minimal slow down effect. Also, if the train is made up of a series of Quantum locomotives in a Consist, and the polarity is set to stop the train, each locomotive in turn will couple the DCC signal through to the DC section until the last locomotive has passed over the boundary; only then will the entire Consist come to a stop.

The above diagram is simplified to make it easy to describe the basic concept. Switch 1 can be a relay powered by a train detector on the next block to do automatic train control. In addition, Switch 1 could have extra contacts to control red and green signals for the actual block signal. Switch 2 could also be part of a relay network for all DC blocks to disable or enable block signal operation.

D1 and D2 should be rated at 2 amps minimum and have a breakdown voltage of 30 volts or more.

Appendix VI

Binary, Hexadecimal, Decimal Conversions

Decimal	Hex	Binary	Decimal	Hex	Binary	Decimal	Hex	Binary	Decimal	Hex	Binary
0	00	00000000	64	40	01000000	128	80	10000000	192	C0	11000000
1	01	00000001	65	41	01000001	129	81	10000001	193	C1	11000001
2	02	00000010	66	42	01000010	130	82	10000010	194	C2	11000010
3	03	00000011	67	43	01000011	131	83	10000011	195	C3	11000011
4	04	00000100	68	44	01000100	132	84	10000100	196	C4	11000100
5	05	00000101	69	45	01000101	133	85	10000101	197	C5	11000101
6	06	00000110	70	46	01000110	134	86	10000110	198	C6	11000110
7	07	00000111	71	47	01000111	135	87	10000111	199	C7	11000111
8	08	00001000	72	48	01001000	136	88	10001000	200	C8	11001000
9	09	00001001	73	49	01001001	137	89	10001001	201	C9	11001001
10	0A	00001010	74	4A	01001010	138	8A	10001010	202	CA	11001010
11	0B	00001011	75	4B	01001011	139	8B	10001011	203	CB	11001011
12	0C	00001100	76	4C	01001100	140	8C	10001100	204	CC	11001100
13	0D	00001101	77	4D	01001101	141	8D	10001101	205	CD	11001101
14	0E	00001110	78	4E	01001110	142	8E	10001110	206	CE	11001110
15	0F	00001111	79	4F	01001111	143	8F	10001111	207	CF	11001111
16	10	00010000	80	50	01010000	144	90	10010000	208	D0	11010000
17	11	00010001	81	51	01010001	145	91	10010001	209	D1	11010001
18	12	00010010	82	52	01010010	146	92	10010010	210	D2	11010010
19	13	00010011	83	53	01010011	147	93	10010011	211	D3	11010011
20	14	00010100	84	54	01010100	148	94	10010100	212	D4	11010100
21	15	00010101	85	55	01010101	149	95	10010101	213	D5	11010101
22	16	00010110	86	56	01010110	150	96	10010110	214	D6	11010110
23	17	00010111	87	57	01010111	151	97	10010111	215	D7	11010111
24	18	00011000	88	58	01011000	152	98	10011000	216	D8	11011000
25	19	00011001	89	59	01011001	153	99	10011001	217	D9	11011001
26	1A	00011010	90	5A	01011010	154	9A	10011010	218	DA	11011010
27	1B	00011011	91	5B	01011011	155	9B	10011011	219	DB	11011011
28	1C	00011100	92	5C	01011100	156	9C	10011100	220	DC	11011100
29	1D	00011101	93	5D	01011101	157	9D	10011101	221	DD	11011101
30	1E	00011110	94	5E	01011110	158	9E	10011110	222	DE	11011110
31	1F	00011111	95	5F	01011111	159	9F	10011111	223	DF	11011111
32	20	00100000	96	60	01100000	160	A0	10100000	224	E0	11100000
33	21	00100001	97	61	01100001	161	A1	10100001	225	E1	11100001
34	22	00100010	98	62	01100010	162	A2	10100010	226	E2	11100010
35	23	00100011	99	63	01100011	163	A3	10100011	227	E3	11100011
36	24	00100100	100	64	01100100	164	A4	10100100	228	E4	11100100
37	25	00100101	101	65	01100101	165	A5	10100101	229	E5	11100101
38	26	00100110	102	66	01100110	166	A6	10100110	230	E6	11100110
39	27	00100111	103	67	01100111	167	A7	10100111	231	E7	11100111
40	28	00101000	104	68	01101000	168	A8	10101000	232	E8	11101000
41	29	00101001	105	69	01101001	169	A9	10101001	233	E9	11101001
42	2A	00101010	106	6A	01101010	170	AA	10101010	234	EA	11101010
43	2B	00101011	107	6B	01101011	171	AB	10101011	235	EB	11101011
44	2C	00101100	108	6C	01101100	172	AC	10101100	236	EC	11101100
45	2D	00101101	109	6D	01101101	173	AD	10101101	237	ED	11101101
46	2E	00101110	110	6E	01101110	174	AE	10101110	238	EE	11101110
47	2F	00101111	111	6F	01101111	175	AF	10101111	239	EF	11101111
48	30	00110000	112	70	01110000	176	B0	10110000	240	F0	11110000
49	31	00110001	113	71	01110001	177	B1	10110001	241	F1	11110001
50	32	00110010	114	72	01110010	178	B2	10110010	242	F2	11110010
51	33	00110011	115	73	01110011	179	B3	10110011	243	F3	11110011
52	34	00110100	116	74	01110100	180	B4	10110100	244	F4	11110100
53	35	00110101	117	75	01110101	181	B5	10110101	245	F5	11110101
54	36	00110110	118	76	01110110	182	B6	10110110	246	F6	11110110
55	37	00110111	119	77	01110111	183	B7	10110111	247	F7	11110111
56	38	00111000	120	78	01111000	184	B8	10111000	248	F8	11111000
57	39	00111001	121	79	01111001	185	B9	10111001	249	F9	11111001
58	3A	00111010	122	7A	01111010	186	BA	10111010	250	FA	11111010
59	3B	00111011	123	7B	01111011	187	BB	10111011	251	FB	11111011
60	3C	00111100	124	7C	01111100	188	BC	10111100	252	FC	11111100
61	3D	00111101	125	7D	01111101	189	BD	10111101	253	FD	11111101
62	3E	00111110	126	7E	01111110	190	BE	10111110	254	FE	11111110
63	3F	00111111	127	7F	01111111	191	BF	10111111	255	FF	11111111

Appendix VII

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