Exhibit E - Part 4

Appendix III A

Recommended DCC Command Stations

Command Station	Recommended	Will Support Service Mode w/ Quantum	Comments[138]
NCE ™	Yes	Yes (See Comments)	Horn and Bell buttons are available but bell button assigned to F3 (see QSI CV 37 example). Newer NCE apparently support programming track but older command stations do not. Programming on the main is easy and straightforward. NCE currently only supports F0-F8 Function Keys.
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 CV29 if you return to 2-digit address. An exception is the obsolete DT100 throttle, which will only program Quantum 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 (all support F0-F12): Super Chief with DT400 Zephyr with DT400 DCS100 with DT400 Chief with DT400See 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 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 cannot be programmed on the main in the standard way (see QSI CV 56.29 for alternative way to program ID numbers). Newer Lens 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.

138 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.

Appendix III B

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”\
- Once the long address is programmed, you must tell the engine to use it.

Enable the Long Address.

- While still in "Program on the Main", press the right turn knob until it says “ad2”
- Scroll with left knob until you get to CV29, then Enter “34” and press "Enter".
- Press “Exit” to leave program mode.

Select Loco with the new Long Address.

- Press “LOCO” and enter new long address to run engine.

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 to CV29. then Enter “2” and press "Enter"
- Press “Exit” to leave program mode.

Select Loco with the Short Address.

- Press “LOCO” and enter Short Address to run engine.

Appendix III C

Programming a Long Address on North Coast Engineering (NCE)

Starting with the engine short address, 003

1. Press "Program": Display reads " Program on Main"
2. Press "Enter:
3. Display shows current 003 I.D. on the display.... Press "Enter"
4. Press #2 for "CV"
5. Enter 17..... Press "Enter"
6. Enter desired "Long Address" i.e. 5200..... Press "Enter"
7. Display reads "Activate this Address?"..... Press 1 for Yes
8. Display reads "Enter CV Num?"..... Press "Enter"

You are now out of program mode and have completed "the Long Address" sequence.

Appendix IV

Troubleshooting

Operations Mode

My headlight does not come on when I start my engine out but mysteriously comes on whenever I blow the horn or turn on the bell. Also, if I try to turn on the headlight, it 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 on the lighting with the F0 key, the state for the light may already be on at the base station but not sent. When you press the F0 key, it toggles the lights to be off and sends that command. It takes a second press of the F0 key to send another command to turn on the light.
My brakes, bell, air release, or other sounds comes 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 or off when a Function Group One or a Function Group Two is sent.
My engine makes no sounds except an air release when power is applied and will not operate.	You have your engine in Shut Down. Double press the F6 Start-Up key to start you locomotive.
My engine 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 engine does not speed up but instead, the directional lighting comes on.	Your engine 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 Key, the engine speeds up at low throttle settings.	Your engine 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 engine 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 a certain throttle settings.	The top speed of your engine is dependent on the gear ratio, load on the engine and the available voltage applied to the track. Asking the engine to go faster results in no change. (See CV 56.10 for 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 you speed step setting on your base station. To get 1 smph you need to be in 128 speed steps.
In Throttle Control Mode, there are no speed changes above a certain throttle settings.	Try a different speed curve or define you own to provide full range of throttle motion.
My engine operates with no problem in DCC, but does not operate at all under Analog control.	Make sure Analog operation is enabled. CV29 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.

Service Mode Operation

My Quantum equipped engine will not program in Service Mode with my command station.	Some command stations do not provide sufficient current to power the Quantum system. Use Ops Mode programming. You can also purchase from Tony's Train Exchange®139, 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 CV, the reported value is off by one digit.	This is timing issue with some command stations. Either program in Ops Mode or considering using a PowerPak.
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 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.

[139] Tony's Train Exchange; 1-800-978-3427; info@ttx-dcc.com .

Appendix IVa

Using the Quantum Hardware Reset and Volume Controls:

Quantum software can be programmed by the operator to reset the system to factory defaults. As a safety precaution, Quantum also has a backup hardware method to do a system reset. Either method can be used to reset the locomotive to original factory settings. In case your Quantum Sound and Train Control System misbehaves and simply turning the power off from 5 to 15 seconds does not return it to normal operation, you can reset your engine using CV 56.128 or you can use the hardware Reset Jumper found on earlier Quantum Systems or the Magnetic Wand to activate a reed switch included on more modern Quantum Systems.

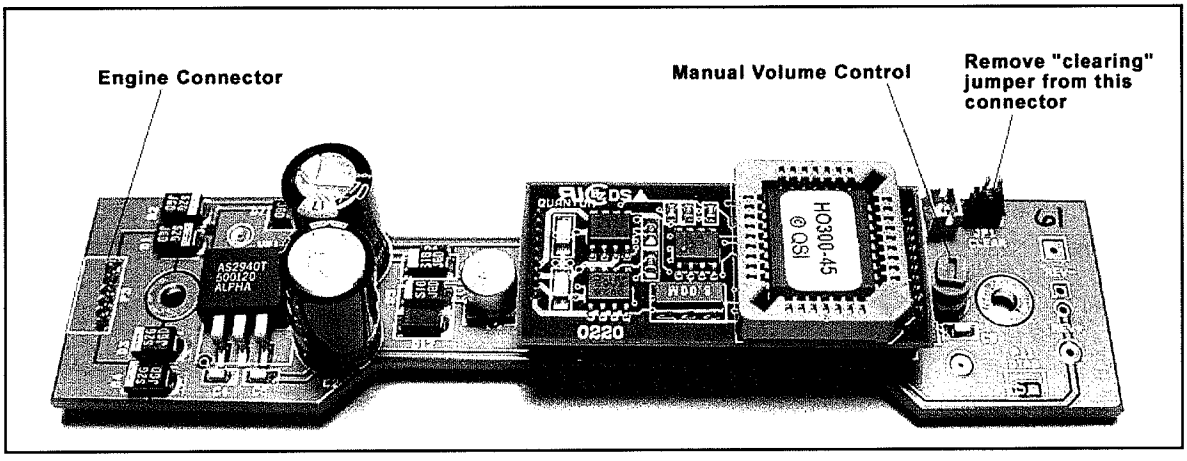
Quantum system volume can also be adjusted using software by programming CV 51.0 or by a hardware volume adjustment. Earlier Quantum systems used a potentiometer volume control and later models use a magnetic wand.

Reset Jumper Models

Both early Quantum steam and diesel used jumper and volume potentiometer to control reset and sound volume. The diagram below shows a Quantum circuit board used in some Steam Locomotive tenders. The jumper and volume potentiometer is located on the bottom board as shown in the diagram below.

To Reset the Locomotive:

- Turn off the main track power.
- For Steam Engines, remove the tender body or water filler hatch to reveal the circuit board. If it is a plastic tender, there are no screws; it is a press fit to the chassis. Die cast tenders will have retaining screws under the chassis. Most diesels will have a removable access panel over the Quantum circuit board on the roof. The location of the access panel will be shown in the Steam or Diesel Model Specification sheet that was included with your locomotive instructions.
- To reset the Quantum system to its default values, locate the black "clearing" jumper (see below) and remove by pulling it up.
- Reapply main track power, the horn and/or bell will sound after a few seconds.
- Turn main track power off and reinstall jumper, and tender cab or access panel. The locomotive has now been returned to original factory settings including all Analog and DCC settings.



Note: Do not try to perform the jumper reset operation on the Program Track under Service Mode power. Always perform this operation under full power.

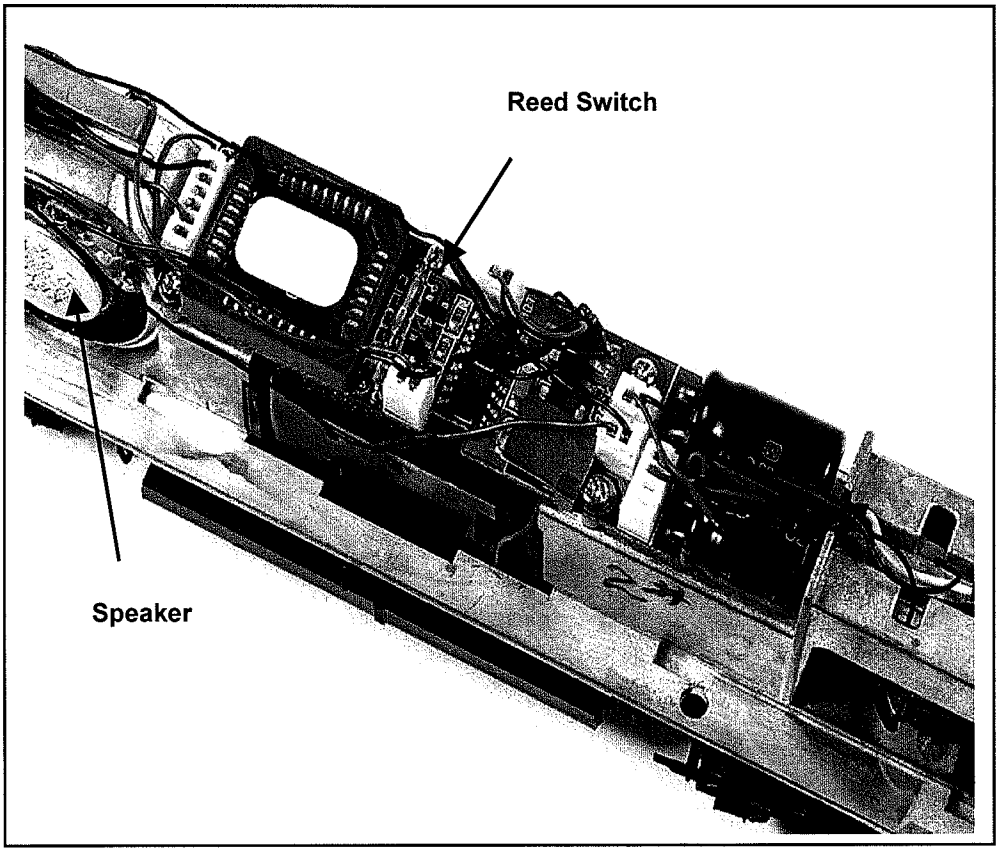
To Adjust the Volume Using the Potentiometer:

- Locate the Manual Volume Control under the access panel on the roof of your diesel locomotive or under the water hatch on Steam Locomotive tender as shown in the Diesel Model Specification sheet that was included with your instructions.
- Turn on main track power. You may want to turn on and leave on some of the significant sound effects such as whistle/horn and bell.
- Use a small screwdriver to turn the volume clockwise to increase volume or turn it counterclockwise to decrease the volume.
- Replace the access panel or water hatch cover.

Note: Volume can also be adjusted digitally using the programming methods described in the programming sections of this manual.

Magnetic Wand Models

Modern Quantum steam and diesel models use a glass enclosed reed switch to reset the Quantum System or adjust the volume. The reed switch will close its contacts when the magnet supplied with your locomotive is placed in close proximity. The advantage of this method of adjusting your engine's volume or resetting it to factory defaults is that you do not need an access panel to gain access to the controls. Also the wand does not need to touch the body; it can be held a reasonable distance from the roof area to prevent possibly marring the painted surface.



Quantum small diesel board with a reed switch mounted in a narrow-body diesel

To Reset the Locomotive:

- Locate the reed switch area as shown in the *Diesel or Steam Model Specifications* sheet that was included with your model.
- Turn off the track power.
- Place the Magnetic Wand over the reed switch area and re-apply track power and leave the wand there until you hear the word "reset". Remove the magnetic wand, your engine is now reset.

The locomotive has now been returned to original factory defaults including all DCC and Analog values.

Note: Do not try to perform this reset operation on the Program Track under Service Mode power. Always perform this operation under full power.

To Adjust the Volume Using the Magnetic Wand:

- Locate the reed switch area on the locomotive's roof as shown in the *Diesel or Steam Model Specifications* sheet that was included with your model.
- Power up engine and leave in Neutral.
- Place the enclosed Magnetic Wand over this reed switch area on the roof of the locomotive's roof perpendicular to the track and wait as you hear the volume increase or decrease in incremental amounts as the Horn hoots about every second. Move the wand away and again place it over the reed area to change the direction (louder or softer) of the volume change. Remove the wand when you reach the desired volume level.

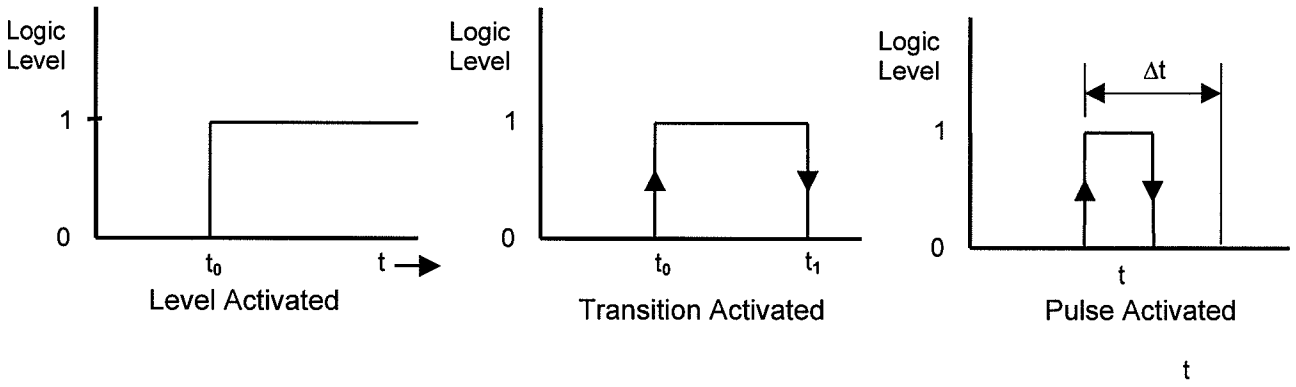
Appendix V

Different types of Feature Operation from Function Commands

QSI will often use the same function to control different effects depending on whether the system is in Neutral or a Motive state (Forward or Reverse). This allows us to increase the number of features available to DCC functions over the NMRA specified maximum of 14 (FL(f), FL(r), F1-F12). In addition, many QSI features respond to the Function inputs in different ways. It is the purpose of this section to describe how different Quantum features respond to function commands and help you get the most out of operating your locomotives. Also, if you intend to make your own output assignments for features using CV 53, it is important to know the implications of different types of features assigned to Neutral and to Forward/Reverse States for the same output.

Classification of DCC Signal Types

There is only one kind of function signal for DCC; either a function is "on" and transmits "1's" every time the command is sent or "off" and transmits "0's" every time the command is sent. However, Quantum has three different ways to respond to DCC function signals as illustrated below.



Level Activated: This is classic response to a DCC function signal. If the DCC function signal is sent at level 0, the feature is not activated. If the DCC function signal is sent at level 1, the feature will activate. The above figure on the left shows a function signal being sent out at t_0, where the level changes from "0" to "1" occurs which will cause a Level Activated feature to respond. One possible advantage of Level Activated Signals is that the operator may know the status of a feature[140] by knowing the logic level that has been sent. However, since function signals are not continuously transmitted, the status of a feature prior to t_0 may not be known unless there had been a recent change to that function or to another function within the same function group.

Another advantage of Level Activated Features is that all locomotives in a Consist receive the same known command. For instance, if the horn feature is turned on, all locomotives blow their horns or if the Mute Feature is activated, all engines will mute their sounds or if directional lighting is turned off, all engines shut down their lighting.

Transition Activated: In this case, the feature is activated whenever there is a transition from level 0 to level 1 or from level 1 to level 0. In the above middle figure example, there would be a feature activation at t_0 and a second activation at t_1. Since the feature is not responding to the logic level of the function signal, the value of the logic level cannot provide any information about the status of the feature.

Pulse Activated: Two transitions within a time period, Δt, is required for a Pulse Activated Feature to respond. It makes no difference if the pulse starts at level 0 or at level 1. The figure above shows a transition from level 0 to level 1 followed by a return to level 0, all within the allotted time period, Δt. The advantage of a pulse activate feature is that it cannot be accidentally activated.

[140] This also depends on the type of feature. If it is a triggered feature such as an Air Let-Off, then the logic level provides no information.

Classification of Feature Types

Toggled Features: Features that switch between two states in response to a function command are toggled features. For instance, the Bell sound is a toggled feature; once it is turned on, it stays on, until it is commanded to turn off.

Toggled Features can be activated by any of the above function signals although we generally use Level Activation to operate toggled features. In this case, a Level 1 signal will cause the feature to be in one of the two known states, while a level 0 signal will cause it to be in the other known state. This allows the operator to know which state the feature is in by knowing the status of the function signal at his command station or his handheld. For instance, if the feature is a light which can be changed between on (level 1) and off (level 0), then the operator will know the light has been turned on when he sends a level 1 function signal, even if he cannot see the locomotive.

The Horn is also a toggled feature, which we assign to F2 as its factory default function key. When the F2 key is activated, then "1's" are sent and the horn sound comes on. The Horn will continue to blow until the F2 key is pressed again to produce "0's" whereupon the horn sound feature will turn off and stay off.

Some command stations have a horn button that can be pressed to operate the horn effect. The Horn sounds when the horn button is pressed and then turns off when the horn button is released. However, the horn button is a custom feature on those DCC controllers and does not act like a normal F2 function key. The horn button is designed to generate "1's" whenever the horn button is pressed and held down and send 0's when the horn button is released. Hence, while the Horn seems like a Momentary Feature when using the horn button, it is actually a Toggled Feature.

Other Toggled Features on Quantum include, Bell, Mute and Blower/Fans. While State Features can be affected by the directional state or other states in the locomotive, the features are nevertheless either "on" or enabled or "off" or disabled until changed.

Level Activation signaling is now assigned to most Toggled Features in Quantum. Air Brakes and Cruise Control on the Lionel® Challenger and the Gas Turbine are the only remaining toggled features that responds to Transition Activation.

State Dependent Toggled Features: Features may also change their state depending on other inputs besides function signals. The status of some features may change when power is turned off and reapplied, or the engine changes its motive state or the speed is changed. For instance, the Bell sound will turn off if power is cycled from on to off to on; Dynamic Brakes will shut off when the speed is reduced below 7smph or whenever the directional state of the locomotive is changed.

Momentary Features: These are single event features that return to their original status after they are activated. Examples are Air Let-offs, Brake Squeal in Forward and Reverse, Doppler shift and Neutral Events like Pop-off, Blow Down, etc. All Quantum Momentary Features are Transition Activated. Although it is possible to use Level Activation, it would seem to have limited use. For instance, you could have an air let-off respond only when the function signal goes to level 0 from level 1 but not respond when going from level 1 to level 0. This would provide an air-let off, every other time the function key was pressed.

Progressive Features: A Progressive Feature does two things when operated: 1) it activates the currently enabled feature and 2) it enables the next feature. The next time it is operated, it activates the newly enabled feature and enables the next feature. After no more features can be enabled, additional function signals have no affect. An example of a Progressive Feature is engine Shut Down. There are three stages to the shut down operation. Double pressing the F9 Key on an engine in Neutral will put it in Disconnect; the next double press operation of the F9 Key will put it in Standby; the next double press operation of the F9 Key will cause it to enter Total Shut Down. At this point, operating F9 key will have no further effect.

Both the Shut Down and Start Up features are Pulse Activated. This requires that the function key be double-pressed within one second to activate this feature. Double pressing ensures that this feature is not entered accidentally.

Enabled Features: Enabled or armed features are set to react to a second signal or condition to active the feature. An example is coupler arming which later generates a coupler opening sound effect when the Function Key is pressed again at a later time. Armed Features are unique in that they can supplant a specified feature's

reaction to a function signal until the features is triggered. The Coupler Fire feature is an example of this since this feature will not occur until the coupler sound features is armed.

Take Control Features: These are automatic features that can also respond to function key signals. Once the function signal is received, the automatic operation is disabled and the "Take Control" operation is enabled. That feature is then under complete control of the Function Key output signal. For instance, Automatic Blowers/Fans can be toggle to its on or off state by a function key signal and thereafter it looses its automatic operation and now only responds to its function key signal.

With "Take Control" features, there needs to be a way to clear the "Take Control" mode to return the feature to automatic operation. Quantum returns the Take Control feature back to automatic operation when power is turned off and reapplied or if the F6 Start Up Key is operated at any time.

Quantum Features and Control Types

The following table shows each feature that can be assigned to an output and the type of signal used to operate the feature. These include Level, Transition, or Pulse

LA = Level Activated

TA = Transition Activated

PA = Pulse Activated

SD-Toggled = State Dependent Toggled

Feature ID	Feature	Signal Type	Allowed States	Feature ID	Feature	Signal Type	Allowed States
0	Null Output		All	**102**	Directional Mars Light	LA Toggled	All
1	Whistle	LA Toggled	All	**103**	Mars Light	LA Toggled	All
3	Bell	LA Toggled	All	**104**	Strobe Mars Light	LA Toggled	All
5	Dynamic Brakes	LA SD-Toggled	All	**105**	Number Board Lights	LA Toggled	All
8	Blower Hiss/Diesel Cooling Fans	LA Toggled	All	**107**	Directional Headlight + Directional Mars Light	LA Toggled	All
9	Long Air Let-off	TA Momentary	All	**108**	Directional Headlight + Directional Ditch Lights	LA Toggled	All
10	Short Air Let-off	TA Momentary	All	**109**	Directional Ditch Lights	LA Toggled	All
12	Pop-off	TA Momentary	NFF/NFR	**110**	Ditch Lights	LA Toggled	All
13	Blow Down	TA Momentary	NFF/NFR	**111**	Strobe Ditch Lights	LA Toggled	All
14	Injector	TA Momentary	NFF/NFR	**144**	Start Up	PA Momentary	NFF/NFR
64	Mute	LA-SD Toggled	All	**145**	Shut Down	PA Progressive	NFF/NFR
65	Doppler Shift	TA Momentary	FWD/REV	**176**	Air Brakes	TA-SD Toggled	FWD/REV
96	Directional Headlight	LA Toggled	All	**178**	Status Report	TA Momentary	FWD/REV NFF/NFR
97	Directional Reverse Light	LA Toggled	All	**177**	Cruise Control	TA-SD Toggled	FWD/REV
98	Headlight	LA Toggled	All	**211**	Coupler Effect	TA Enable and TA Momentary	All
99	Dim Headlight	LA Toggled	All	**215**	Squealing Brakes	TA Momentary	FWD/REV
100	Reverse Light	LA Toggled	All	**216**	Squealing Brakes + Air Brakes	TA Momentary LA Toggled	FWD/REV
101	Automatic Cab Lights	LA Toggled	All	**217**	Pumps	LA Toggled	NFF/NFR

Quantum Default Features and Control Types

The following table shows our default feature assignments with function activation control and feature types indicated in blue in parenthesis.

LA = Level Activated

TA = Transition Activated

PA = Pulse Activated

SD-Toggled = State Dependent Toggled

Default F-Key	FWD/REV	NFF/NFR
FL(f)	Headlight Directional Lighting (LA Toggled)	Headlight Directional Lighting (LA Toggled)
FL(r)	Reverse Light Directional Lighting (LA Toggled)	Reverse Light Directional Lighting (LA Toggled)
F1	Bell (LA Toggled)	Bell (LA Toggled)
F2	Whistle/Horn (LA Toggled)	Whistle/Horn (LA Toggled)
F3	Coupler Crash-Coupler Fire (TA Momentary)	Coupler Arm (Enable) or Coupler Fire (TA Enabled or TA Momentary)
F4	Steam Blower Hiss/ (LA Toggled) Diesel Fans and Louvers/ Electric Cooling Fans	Steam Blower Hiss (LA Toggled) Diesel Fans and Louvers/ Electric Cooling Fans
F5	Dynamic Brakes (LA SD-Toggled)	Dynamic Brakes (LA SD-Toggled)
F6	Doppler Shift (TA Momentary)	Engine Start Up (PA Momentary)
F7	Brake Squeal-Flanges (TA Momentary) Air Brakes (TA-SD Toggled)	Long Air Let-off (TA Momentary)
F8	Sound Mute (LA Toggled)	Sound Mute (LA Toggled)
F9	Cruise Control (TA Toggled)	Shut Down[141]: Disconnect-Low Idle set-Total Shut Down (PA Progressive)
F10	Status Report (TA Momentary)	Status Report (TA Momentary)
F11	Number Board Lights (LA Toggled)	Number Board Lights (LA Toggled)
F12	Automatic Cab Light (LA-SD Toggled)	Automatic Cab Light (LA-SD Toggled)

The features were designed and assigned to provide the greatest consistency of operation of the different types of locomotives (Steam, Diesel and Electric) as well as maintaining the greatest level of correspondence between the displayed function settings and operating feature status.

Note that FL(f), FL(r), F1, F2, F4, F8, F11 and F12 all are Level Activated Toggled Features. This means that the display for these features is likely to indicate the true status of the features.

Most other features are Transition or Pulse Activated Momentary type, which only responds to changes in the function inputs. Statuses for these features are not required since they return to their initial state after a short period. This includes F3, F6, F7, F9-Shut Down, and F10.

F8, Sound Mute, always comes on it its non-mute state when power is first applied. Since the F-Key status could be displayed as "1" during start up, it may not match the status of the Mute feature in the locomotive. However, the status of this feature is quite evident by the fact the engine is making sound. If the Mute Key is operated even once, the status of the Mute key function display will then match the locomotive Mute status for the remainder of the operating secession.

Since Dynamic Brakes is a State Dependent feature, it status in the locomotive may not match the F-Key function display of "1". However, since the Dynamic Brakes will shut off whenever entering Neutral or slowing below 7smph, unless you hear the Dynamic Brakes or have recently turned them on with a level 1 setting, it is fair assumption that they are off. If the display for F5 is "0", then the Dynamic Brakes are known to be off.

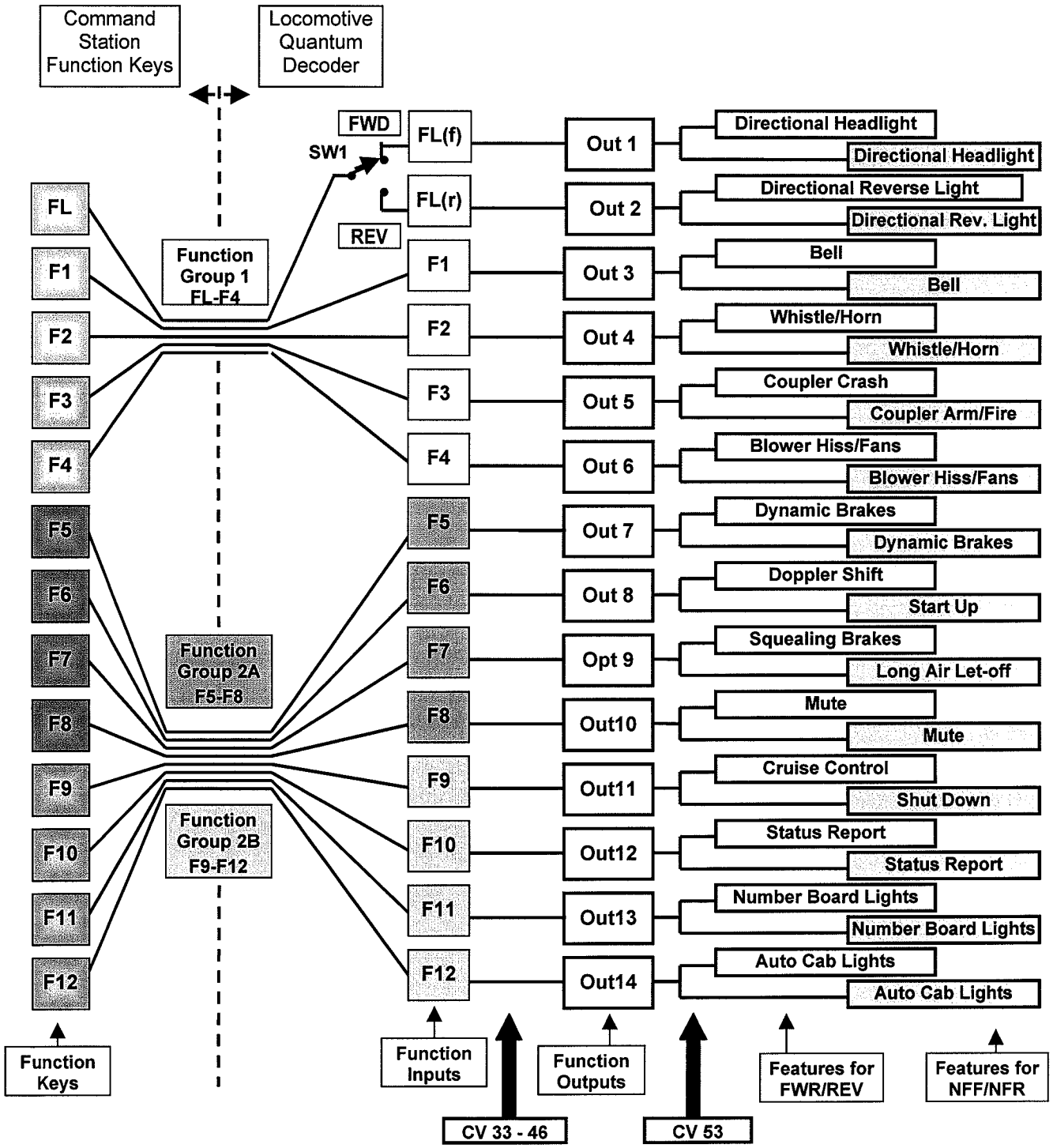
141 There are three stages to Shut Down. To operate Shut down, you will need to double click the F9 key for each stage.

F9-Cruise Control is the only feature that will need to be monitored by observing or listening to the locomotive to determine if the feature is on or off. Since it is a Transition Activated Toggled Feature, the display status of F9 bears no relation to the actual Cruise Control status of the locomotive.

Appendix VI

Interaction of Function Keys, Function Groups, Function Inputs and Outputs and Feature Assignments

The diagram below shows graphically how the Function Keys, Function Groups, Function Inputs, and Outputs are configured and how they interact.



Function Keys and Function Groups: The thirteen colored squares shown on the left side of the dotted vertical line, designated FL, and F1 through F12 represent push buttons or Function Keys located at the Command Station or on the DCC walk-around throttle.

The Function Keys are shown color-coded depending on which Function Group they use to transmit their bit settings to the locomotive's decoder. Keys FL through F4 (Yellow) use Function Group 1 to send information to the locomotive. Keys F5 through F8 (Orange) and Keys F8 through F12 (Gold) both use Function Group 2 but not at the same time. Bit 5 in Function Group 2 specifies whether this Function Group applies to F5 – F8 or F8 - F12. Each Function Group command contains 4 or 5 bit settings for the Function Inputs.

The locomotive's decoder, shown to the right of the vertical dotted line, receives Function Group commands. Whenever a Function Group Command is sent, the function values are stored in memory as a Function Inputs, each with a logic level of 1 or 0.

Function Inputs and Outputs: Each Function Input is shown connected to a corresponding Function Output designed by the squares Out 1 through Out 14.

The boxed labeled "CV's 33-46" with black arrow pointing up indicates that these CV's determines which Function Input controls which desired Function Output. Function Inputs cannot be connected to any Function Output. For instance, Function Inputs FL through F3 can only be connected to Outputs 1 through 8 (see CV 33-37). The diagram shows the default connections between Function Inputs and Outputs. In the description of each CV 33-42, the default Output is shown with gray background [as an example, see CV 41 on page 61, which shows the Output locations for F7. The default is Output 7 (bit 5) and is shown with gray fill, which corresponds to Output 9].

The FL Function Key is special since it connects to two different Function Inputs depending on the locomotive's direction setting. This is shown schematically in the diagram where the position of the single-pole double-throw switch, SW1, is determined by the engine's direction (FWD or REV). In Forward (or Neutral from Forward), the switch, SW1 is in the top position which connects the FL Key to the FL(f) input. When the engine is in Reverse (or Neutral from Reverse), the SW1 would be in the bottom position, which connects the FL(f) Key to the FL(r) Input.

The default Outputs for FL(f) and FL(r) are Out 1 and 2 respectively. If the locomotive is in Forward or Neutral from Forward, the FL key will affect the features connected to Out 1. If the locomotive is in Reverse or Neutral from Reverse, the FL key will affect the features connected to Opt 2. Function Outputs 1 and 2 are generally used for directional lighting effects and are usually assigned to the FL(f) and FL(r) Inputs respectively, which are the Quantum default settings.

Although each Function Input is shown connected to only one Output, there is no restriction in connecting an Input to more than one Output. This can be useful if it is desired to control two our more features at the same time. For instance, it might be desired to have the Bell turn on at the same time the Reverse Light is turned on by the FL(r) Key or to have Ditch Lights operate at the same time the Horn is activated.

Since there are only fourteen Inputs and fourteen Outputs, if more than one Output is connected to an Input, there may be unused Inputs.

Of course, the unused Inputs could be connected to other Outputs that are already assigned but this is not recommended. Because there is more than one Input controlling an Output, it is unclear which Input has control. The software is written such that the common Output would be on if any of its Inputs are on. In other words, the Output is off if and only if all connected Inputs are off[142].

Outputs that are not connected to a Function Input are always off.

Outputs and Features: The box labeled "CV 53" with black arrow pointing up indicates that this CV determines which feature is connected to which Output. CV 53 also allows different features or accessories to be assigned to the Neutral States (locomotive stopped) or to a Motive States (Forward/Reverse). Features shown in the green boxes are assigned to the Motive States and features shown in the red boxes are assigned to the Neutral States. The diagram shows the default Quantum features assigned to the different Function Outputs for Motive and Neutral states.

[142] In other words, the Inputs to a common Output are OR'ed.

Effects of Mixing Different Types of Features: Quantum previously had restrictions on assigning to the same output different types of features with different feature activation methods (Level, Transition or Pulse) for operation in Neutral or Forward/Reverse. The reasons were obvious. If you assigned one feature for operation in Neutral and then another for Forward/Reverse, then the function input would be changed for both. For instance, if the Bell was assigned to output 3 in Forward/Reverse and Number Board Lights assigned to output 3 in Neutral, than there is an issue of what would happen to the Number Board Lights if you turned on the Bell in Forward by sending out a level 1 function and then entered Neutral? The function input for output 3 is still at the new value of level 1. Do the Number Board Lights automatically come on, if previously off?

To avoid this problem, we have a simple rule:

> **An output for a particular directional state (Forward/Reverse or Neutral) will change state, if and only if its Function Input changes while in that directional state.**

There would seem to another way that we could accidentally operate a feature. We could make the change to a feature assigned to an output in one directional state, and after we change to a new directional state, we operate some other function within the same function group. For instance, in the above example, we could turn on the Bell in Forward/Reverse with a level 1 function input signal, followed by operating the Horn in Neutral. Now when the common function group, Function Group 1, command packet is sent, it will also change the function input for output 3 and would turn on the number board lights. However, the above rule still applies since the function input did not change; it remained at level 1, and hence its output did not change. In order for the operator to turn on the Number Board Lights in this case, he would need to send a level 0 function followed by a level 1 function to output 3 while in Neutral.

The main difficulty with mixing different features in Neutral and Forward/Reverse, is that the status of the function at the command station or handheld, does not match the expected associated behavior of assigned toggled features. This is compounded by state dependent toggled features where other inputs can change the status of a feature independent of the function commands and also by Transition or Pulse Activated toggled features, where the function input level has no bearing of the feature status. While an operator may not know what the status of some features are, he does know that whenever a function input is changed, the function input in the Quantum decoder will match the value indicated at the command station or the handheld during an the entire uninterrupted operating secession[143]. The operator can also infer that for most Level Activated Toggled Features, the state of a feature will match the associated level of the function signal directly after sending a function signal. In other words, the operator will know that he has turned on the Number Board Lights directly after he has sent out the appropriate level 1 function for that feature.

Note that these issues only apply to toggled features. There certainly is no issue for Momentary Features, where they always return to their original status, or any other features that are Transition or Pulse activated.

[143] Unless he selects a different locomotive whereupon all indicated function key status may very well have no relationship with the function inputs in the newly selected locomotives decoder.

Appendix VII

Recommended Reading:

Ames, S., Friberg, R., and Loizewaux, 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

Appendix VIII

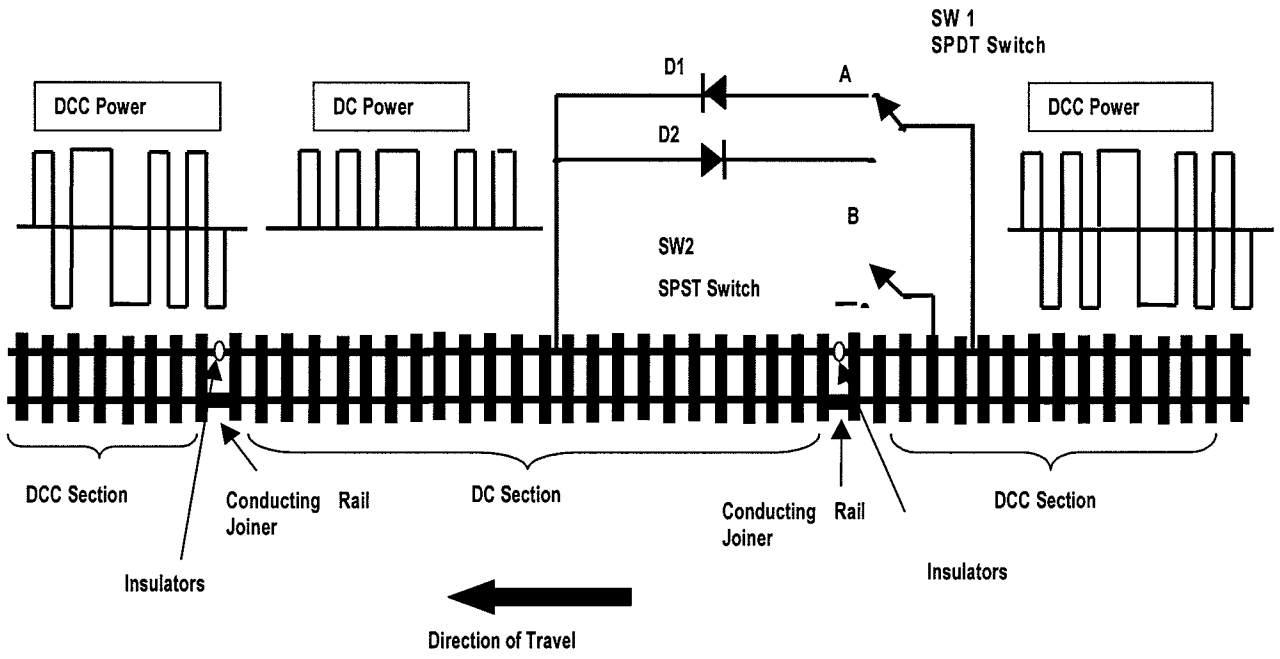
Application Notes:

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 implement into Quantum 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 engine will automatically engage DC Power Conversion when it enters a section of track what is powered with standard DC. If the polarity would normally power the analog engine in the direction it is going when it enters the DC section, the engine will continue through the DC block at the same speed. If the polarity would normally power the engine in the Reverse direction, the engine 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 train or let it precede, depending on the position of SW 1. If the engine is entering the DC section from the right, and SW 1 is set to A, the engine will continue at its current speed setting through the DC section. The engine, 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 engine's direction and the engine will slow to a stop at its DCC momentum setting. If the polarity is reversed again to be consistent with the engines direction, the engine 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 engine, which would also have caused the engine 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 engine wheels pass over the track insulators. In addition, since the Quantum engine is equipped with large filter capacitors, the reduced power of half-wave rectification will not affect the power available to operate the engine so there is minimal slow down effect. Also, if the train is made up of a series of Quantum engines in a Consist, and the polarity is set to stop the train, each engine in turn will couple the DCC signal through to the DC section until the last engine 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 contracts to control red and green signals for the actual block signal. Switch 2 could also be part of 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 IX

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 X

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