M60X CV Listing

This is a list of all CVs used in the M60X that you may customize or change from the factory settings. The "factory value" column lists the original factory settings for a new decoder or after a decoder reset command is received.

CV #	Factory Setting	Value Range	Description
CV1	3	0-99	1-99 Primary Address
CV2	9	0-255	Motor Starting Voltage MSV
CV3	2	0-255	Motor Acceleration Rate
CV4	2	0-255	Motor Deceleration Rate
CV5	255	0-255	Maximum Motor Voltage Vmax
CV6	128	0-255	Mid-point Motor Voltage Vmid
CV8	135	135	CVP Manufacturer ID
CV11	0	0-255	Loss of Signal Timer (seconds)
CV17	0	0-255	Loco Address Hi-Byte
CV18	0	0-255	Loco Address Lo Byte
CV29	2	0-255	Decoder configuration
CV35	0	0-15	F1 Function Key Action [none]
CV36	0	0-15	F2 Function Key Action [none]
CV37	0	0-15	F3 Function Key [none]
CV38	15	0-15	F4 Function Key Action [none]
CV39	1	0-15	F5 Function Key Action [CRUISE]
CV40	0	0-15	F6 Function Key Action [none]
CV41	0	0-15	F7 Function Key Action [none]
CV42	0	0-15	F8 Function Key Action [none]
CV43	4	0-15	F9 Function Key Action [none]
CV44	2	0-15	F10 Function Key Action [none]
CV45	3	0-15	F11 Function Key [A1]
CV46	4	0-15	F12 Function Key Action [A2]
CV47	3	0-15	A1/A2 Period or rate
CV48	2	0-15	A1 Special Effect
CV49	2	0-15	A2 Special Effect
CV56	0	0-255	Bump Amount
CV57	0	0 - 127	Bump duration in us
CV59	3	1-15	Headlites Effect Period (x512ms)
CV60	0	0-15	Headlights Mode 0=normal/autorev
CV61	4	0-15	Headlight Front Effect
CV62	4	0-15	Headlight Rear Effect
CV63	0	0-1	Cruise Mode - 0 Norm, 1=Track
CV64	4	1-16	Cuise Track Rate (ms)
CV65	2	1-3	Cruise Track Step Size
CV96	0	0-1	Select A1/A2 or Ditch lite mode
CV200	0	0-16	RF Frequency number

The AirWire900® M60X™
Motion Decoder User Guide

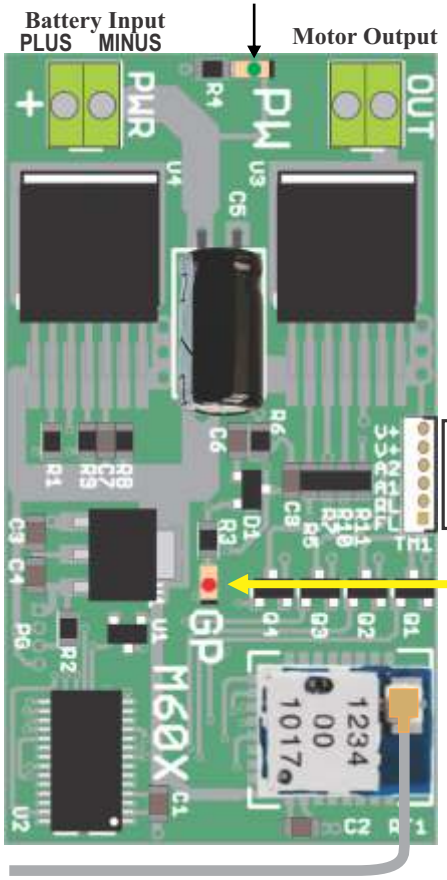
Contents

- M60X Decoder
- Whip Antenna
- Light Driver Cable
- JST-SKT Battery Cable
- Polarity Test Diode
- This User Guide

M60X Decoder Connections

PW Green LED

On when battery power is on



Warning - Battery Polarity

Reversing the battery polarity will destroy the M60X.

Motor Polarity

With your throttle set for forward, and the speed turned up, the locomotive will move forward. However, if the locomotive goes backward instead of forward, reverse the two motor wires at the terminals.

LED Driver Outputs

V+	Battery Voltage Source
V+	Battery Voltage Source
A2	A2 Light Driver
A1	A1 Light Driver
RL	Rear Light Driver
FL	Front Light Driver

GP Red LED

On when any throttle data is received on the selected frequency (regardless of loco address)

Radio Module

Keep wires and other metal objects away from the radio module.

Whip Antenna

Antenna gold connector rotates to desired position. It is removable. Replacements available.

M60X Board Familiarization

1. Battery Input Terminals: Connection to the battery goes here. The positive terminal is labeled with a + sign. The M60X battery input is polarity sensitive. **Reversing the polarity will destroy the M60X.**

2. Motor Drive Output Terminals : Connect these two terminals to the motor.

3. Green PWR LED Indicator: Glows bright green when power is applied.

4. Red GP LED Indicator: Glows steady bright red when an AirWire throttle is set to the M60X's frequency.

5. Radio Module: This is the sensitive radio receiver. Keep the antenna away from all wiring for best reception.

6. Removable Antenna: The M60X comes with a small 3.5 inch whip antenna. This whip antenna is plugged into a small jack on the radio module. The antenna is removable. The antenna jack can be used with different types of external antennas. The optional WEC, from CVP Products, allows the whip antenna to remotely located away from noisy motors with the benefit of an improved reception range.

For Longer Range - Consider The WEC

The whip antenna can be unsnapped from the radio module and snapped onto a Whip Extension Cable (WEC). The other end of the WEC snaps onto the radio module. The WEC is about 14 inches long which is of sufficient length to move the antenna far away from noisy motors and wiring.

It OK to bundle the WEC cable with other wiring. The cable's shield protects against noise pickup. Use tie-wraps secure the cable.

Just about any location away from noisy wiring works best to mount the antenna. It can be mounted on the outside of the shell. Non-metallic paint can be used to disguise the antenna.

Orienting the whip vertical is usually the best. However, horizontal also works. Try both and pick the one that provides the best range for your railroad.

Antenna Orientation

For best range and operation, the whip antenna must be vertically oriented. This can be done by mounting the board vertically or simply bending the antenna.

If you bend the antenna, do so gently. Bend the antenna vertical at the point where it exits the tubing portion of the connector. Straighten out any kinks so that it favors a vertical orientation and stays upright by itself. The gold connector on the antenna freely rotates on the radio module.

Take care not to unsnap the antenna connector. If it does come off, center it over the connector and push straight down to snap it back on.

Absolute Maximum Ratings

Maximum Input Battery Voltage	24 Volts DC
Minimum Input Battery Voltage	8.2 Volts DC (7.8 typ)
Maximum Motor Output Current - Pulse	55 A
Motor Over Current Trip	6.5 A
Maximum Continuous Motor Output Current	6 A at 25°C
Maximum LED Driver Output Current	1 Amp per output
Thermal Shutdown	@100C
Reverse Polarity	Not Protected
FCC ID Number X7J-A10040601	Part 15 Compliant

M60X Decoder Warranty Information

This warranty covers substantial defects in materials and workmanship in the M60X decoder.

What This Warranty Does Not Cover

This warranty does not cover any problems which result from improper installation, modifications, battery polarity reversal, improper operation, leaking batteries, excessive battery voltages, excessive motor current draw, connections to 3rd party circuit boards, abuse, accidents, or acts of God such as excessive heat, floods, damage caused by exposure to moisture and rain, lightning, earthquakes, thunderstorms, hail storms volcanic events, tidal waves or hurricanes.

Warranty Duration

The coverage of this warranty lasts for 90 days. After this period, standard repair rates apply. Depending on the problem, CVP reserves the right to repair or replace.

Repairs and Returns

If you purchased your M60X decoder from one of our AirWire900 dealers, please call them first. They are your best and quickest for answers to questions about M60X decoder. They are also experts in installation and offer such services should it be required. If you purchased your M60X decoder ***directly*** from CVP Products, call us first.

If you are asked to return an item to CVP for service, you must follow the instructions on the website. See the red box labeled, "Repair Services." There you will find the street address plus other helpful tips about sending packages to CVP Products. You must obtain an RMA. **Do not send items to us for repair without first obtaining the RMA.**

Battery Won't Charge - Tips And Common Mistakes

Lithium-Ion rechargeable batteries are remarkably robust with a long life. However, proper charging procedure and equipment is mandatory.

Accidental Short Circuit Of Battery Wires
If the plus and minus wires come in contact with each other or through a wiring error, the battery's internal protection circuit will trip. The battery voltage will be zero volts. To reset the protection circuit, momentarily connect the charger to the battery. This will reset the protection circuit and restore normal operation.

How Long Will A Battery Last
This is a very common question that does not have a simple answer. This is because the answer depends on many factors such as: type of railroad, locomotive condition, temperature, how the railroad is operated, how many cars are pulled, how many hills and so on.

A Fully Depleted Battery Will Measure 0 Volts
The battery has internal protection that shuts off the output voltage when the battery is fully depleted. Thus a battery will measure 0 volts on an voltmeter. There is nothing wrong with the battery. Recharging the battery will restore normal output voltage.

Use Battery Charger Designed For Lithium-Ion Batteries
This type of charger is typically called a "smart" chargers. A smart charger is required to properly charge the battery and to keep it charged or "topped off" after charging. A smart charger can remain plugged into the battery indefinitely. Using any other type of charger will shorten the life of the battery as well as not charge it to full capacity.

Match Charger Voltage To Battery
For a 14.8V battery, the charger must also be set or designed for 14.8V.

Allow Sufficient Charging Time
With a charger rated at 1.5A, a fully depleted 6.8Ah battery will take about 4.5 hours to reach full charge. If your charger has a different current rating, divide the Ah rating by the charger output current. The answer is the number of hours to charge a fully depleted battery.

If You Suspect You Have A Bad Battery...
Remove the battery. Connect it directly to the smart charger. Verify the charger indicates charging. Let is charge overnight. Measure the battery voltage after charging. A fully charged 14.8V battery, will measure about 16.5 volts. Your battery may be faulty if the charger never stops "charging" or never begins to charge. If the battery still measures 0 volts after charging overnight, it will require replacement.

Batteries Do Last A Long Time - But They Don't Last Forever
With normal operation and the use of a smart charger, you can expect the battery to sustain between 500 and 700 charge/discharge cycles before it needs replacement. This means the battery will provide many years of operating enjoyment.

Off Season Battery Storage Tips
Remove the batteries from the trains. Don't charge the battery before storing. The battery lifetime is enhanced if it is stored partially depleted instead of fully charged. Store batteries in a cool and dry environment. When it is time to put the battery into service, allow it warm to room temperature before charging.

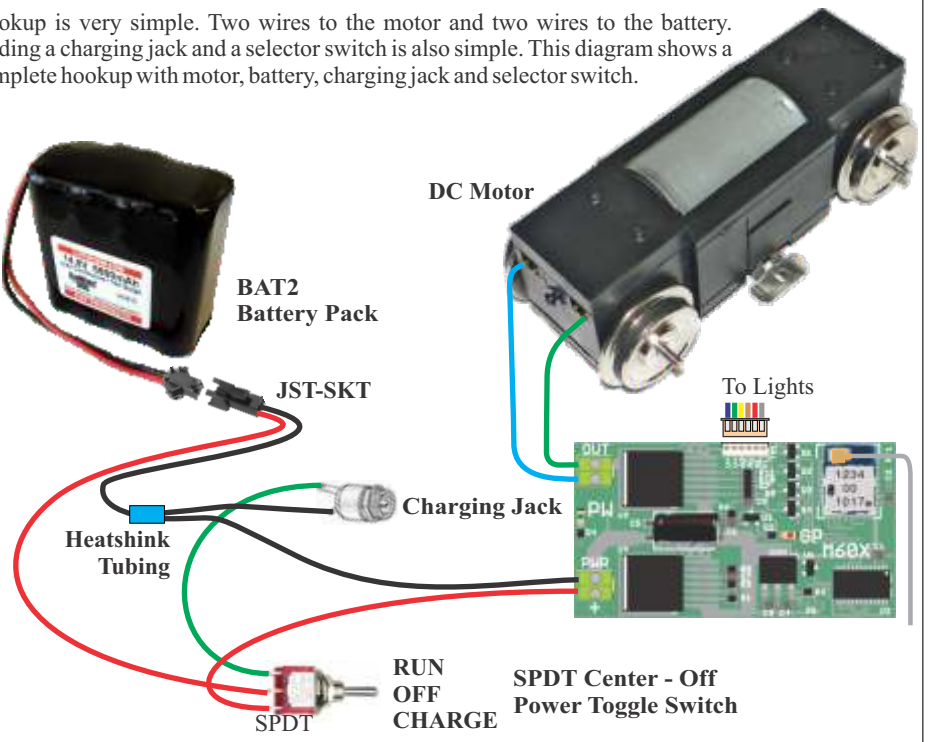
Thermal Management

On rare occasions, your decoder may become too hot and shut down to protect itself. No harm has occurred to the decoder if this happens. The decoder will resume normal operation when its internal temperature drops below its over-temperature trip value which is about 100C. Hot climates and higher battery voltages contribute to overheating.

Consider improving airflow to the decoder. And consider lowering the battery voltage. The amount of heat dissipated by the M60X is based on motor current and battery voltage. Using a lower voltage battery means the top speed will be slower, but the battery will last longer. Just like real railroads, using multiple locomotives in a consist is more efficient than a single locomotive.

M60X Decoder Hookup Diagram

Hookup is very simple. Two wires to the motor and two wires to the battery. Adding a charging jack and a selector switch is also simple. This diagram shows a complete hookup with motor, battery, charging jack and selector switch.



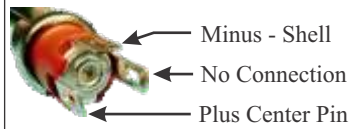
Charging Jacks and Cords, Other Nice To Haves

From the Digikey Catalog - www.digikey.com

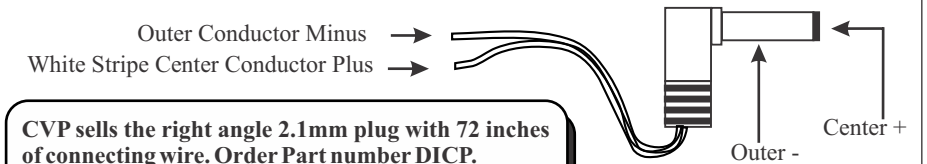
Description	Part Number
Heatshink tubing assortment kit	Q842-KIT-ND
Switchcraft 2.1mm DC Power Jack - Panel Mount	SC-3508
SPDT Miniature Toggle Switch - Panel Mount	2449-ANT11SECQE-ND

From CVP Products AirWire Catalog - www.cvpusa.com

2.1mm Plug with 24 inches of 2-conductor stranded wire	DICP
Matching socket for CVP Battery Plug	JST-SKT



Switchcraft 2.1mm DC Power Jack
721 Series Panel Mount with Nut/Washer



CVP sells the right angle 2.1mm plug with 72 inches of connecting wire. Order Part number DICP.

DCIP Cable

Recommended Soldering Tools and Solder

Soldering small wire is not difficult. However, if you don't have the correct tools, proper soldering is difficult and frustrating.

Use Small Diameter Rosin Core Solder. The choice of solder is also important. One of the things to remember is to never use acid core solder. Acid core solder will destroy the board and components. The best solder for electronics work is small diameter, 0.015 to 0.02 inch "no-clean-flux" core solder. Larger diameter solder should not be used as there is a risk of putting too much solder on the pad which will short out adjacent pads.

Use A Small Diameter Soldering Iron. Don not use so-called soldering guns. These are very high wattage and will damage delicate traces, pads and components. A 30-60 watt, temperature controlled iron is the best.

Tool Source: The following part numbers and prices are from Digikey Electronics.

www.digikey.com

Spark Fun Soldering Iron, 60W, Adjustable Temp	1568-14456-ND
Soldering Iron Holder, Tip Clean Sponge	2260-AO2663-ND
60/40 Rosin Core No-Clean Solder	315-NC2SW.0151OZ-ND

Keep The Soldering Tip Clean. Buy an inexpensive soldering iron stand, that includes a holder for a small sponge. Keep the sponge damp. Swipe the tip across the damp sponge to clean it before soldering. Don't clean it after soldering - the excess solder protects the tip. Before turning off the iron's power, put a blob of solder onto the tip. This solder coats the tip and prevents oxidation.

Always Twist and Tin Stranded Wires Before Using. Stranded wire must have their individual strands twisted together followed by a applying a small amount of solder - this is called tinning. It makes soldering the wire to the board much easier.

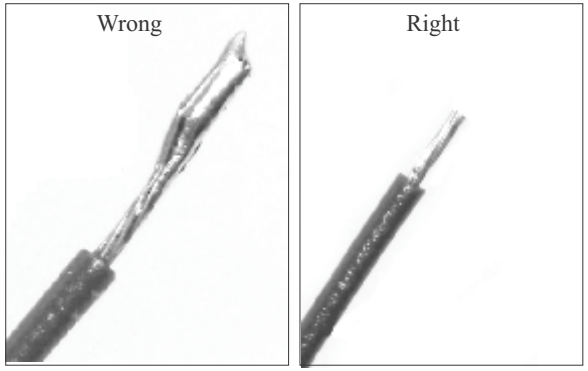
Soldering Tips

- Do Not use too much solder. A tiny amount is all that is needed.
- Never apply the solder directly to the iron and attempt to 'paint' it onto the lead.
- Proper soldering takes a little patience. This is the most important part of learning to solder. You must watch and wait if you want to have a good solder joint. Soldering can not be rushed.
- When the joint has cooled, trim the excess lead using the wire cutters. Do not cut off the solder joint - rather trim the lead to the top of the joint.

Connecting Wires To Terminal Strips

If using stranded wire, always tin the wires. Here's how to do this.

Remove about ½ of an inch of insulation from the wire. Tightly twist the individual strands together. Use a soldering iron and heat the wire. Then apply a small amount of solder to the wire strands. This process, called tinning, keeps stray wires from shorting across to the adjacent terminal or to other areas of the board. Trim the tinned wire to about 1/4 inch.



When inserted into the terminal, only a tiny part of the bare wire will be visible.

Notice that the wire has been trimmed in the "right" image.

Always use different wire colors.

The terminals will accept wire as large as 20-22 AWG. However, the twisting and tinning may thicken an already large wire to the point where it doesn't fit. If so, redo it and twist the strands tighter

Battery Buying Precautions

Purchasing Batteries - Precautions

There are hundreds of sources for Lithium batteries and packs. Their widespread use in consumer electronics, RC cars, drones and planes means they are relatively inexpensive and come in lots of different sizes. Beware that many batteries in the RC hobby market do not have a built-in protection circuit board (PCB). If the battery feature list doesn't state that it is protected, then it does not have pcb. Don't use this battery. Instead, look for cells that specifically state that the PCB is included. Some vendors use the acronym PCM which stands for Protective Circuit Module. PCM or PCB mean the same thing - the cell is protected.

Battery marketing information is sometimes confusing. Lithium-Ion (Li-Ion) batteries are the most commonly available rechargeable battery. So are Lithium-Polymer. Some vendors claim one is better than the other. However, don't be fooled. The "Po" is short for polymer and simply means the Lithium-Ion battery is in a plastic pouch instead of a hard cylindrical shell. They are both Li-Ion batteries.

CVP Products Li-Ion Batteries

CVP Products offers two suitable batteries that fit most large scale locomotives. Both batteries are Lithium-Ion type and include built in protection circuit boards. They are equipped with CVPs standard JST-PLUG connector.


BAT2

BAT2 is an 8 cell 14.8V battery pack with a 6.8Ahr capacity. The dimensions in inches are 2.8L x 1.5W x 2.8H. It is fully protected. Its weight is 14oz. Two BAT2 can be safely wired in parallel.


BAT3

BAT3 is a 4 cell 14.8V battery pack with a 3.4Ah capacity. The dimensions, in inches, are: 1.5L x 1.5W x 2.8H. It is fully protected. Its weight is 14oz. Two BAT3 can be safely wired in parallel.

Other Li-Ion Battery Suppliers

The 2 companies listed below are good sources of all types of rechargeable batteries. Each offers literally hundreds of cells and battery packs. There are many more vendors but they come and go at a furious pace. It may be beneficial to spend some time shopping on the Internet to compare prices and availability. Be sure to check Amazon too but read the battery descriptions carefully.

One precaution when purchasing on the internet. Beware of sellers that don't show stock availability. They will take your order, charge your credit card but might not ship your order for many weeks or months. If availability is not stated, call the supplier and ask. But if they don't know or won't tell you, take your business elsewhere. Don't support this unethical business practice.

Finally, beware of extra fees when ordering batteries. Some vendors may tack on an extra handling fee, implying that it is fee charged by the carrier. However, there is no such fee when batteries are shipped via ground service. Always request ground service, usually UPS.

Tenergy Power
436 Kato Terrace
Fremont CA 94539
(510) 979-9969
https://power.tenergy.com

PowerStream
1163 South 1680 West
Orem UT 84058
(801)764-9060
www.powerstream.com

*** Caution**

When ordering batteries, always request United Parcel Service (UPS) **Ground** Shipping. Some vendor of batteries, but not all, may add "Hazardous Material Handling Fees" or other special handling fees when shipping Lithium batteries.

Battery Considerations And Options

Available Space - Use A Dummy Loco or Trailing Rolling Stock For The Battery

The simplest installation is where the battery is contained inside a dummy locomotive, box car or even a flat car. Not only can a larger battery be used, there is room for a charging jack, connector and toggle switch. Two small wires connect between the battery car and the locomotive where the decoder is located.

Another consideration is to put everything inside the dummy loco or trailing car including the decoder. This allows multiple locos to share a single decoder and battery. The downside of this approach is the need for more wires if you intend to use the decoder's light outputs on the lead locomotive.

Tip From The Experts: If using a dummy locomotive, consider adding internal lighting inside the dummy and make it the lead locomotive. Then, only two wires for the motor connect to the trailing locomotive. The trailing locomotive is used to push the lead locomotive.

Battery Voltage

The battery voltage rating is what the motor will receive when the throttle is at 100% of top speed. If your locomotive is primarily used as a slow speed switcher, the M60X will work with voltages as low as 8.2V volts.

Runtime or Battery Capacity

A battery's capacity is labeled on the side of the battery. For small batteries, the label will usually list the capacity in milli-Amp-hours. If the label says 1500mAh, the battery will deliver 1.5A for one hour. If it says 3400mAh, the battery will deliver 3.4A for one hour.

Battery capacity and battery voltage dictate the battery's physical size. A low voltage battery will have a higher mAh rating than a high voltage battery of the same size. But the high voltage battery will have a significantly lower capacity.

Battery Protection

Lithium battery packs are extremely safe with exceptionally long lifetimes when they are equipped with an internal protection circuit board. When buying battery packs, make sure it has the protection board built in.

Battery Packs With Extra Plugs And Sockets - Can I Use Them?

Yes! This type of battery pack is inexpensive and readily available. It is most commonly used with RC Drones, cars and paint-ball guns. These packs do not include the protection circuit board.

The 11.1V pack will have three 3.7V cells in series. The "Cell Balance" connector provides access to the individual cells that make up the pack. It is used by a special smart charger to insure the pack's cells are safely charged to maximum capacity.

With the cell-balance connector and a smart charger with the cell balance feature (sometimes called a "LiPo Charger") the charger monitors the charge on each individual cell and insures that each cell is charged to the maximum capacity. If one cell requires more time to reach full capacity, the charger will charge that cell a bit longer than the others.

If your smart charger doesn't include the cell-balance feature, then the smart charger can only monitor the full pack voltage. It will monitor the pack voltage of 11.1volts and use this voltage plus the average charging current of the pack to determine when to terminate the charge. The balance connector is not used and nothing connects to it. Leave the connector attached - don't cut it off. Cutting off the connector risks shorting out the cells which will destroy the pack.

Recommended Battery and Charger

A 14.8V, Lithium Battery Is Recommended - We searched high and low for a suitable battery along with a matching charger at an affordable price. While you are not required to use our recommended battery pack and charger, they offer the best compromise among many factors such as safety, power, size, weight, voltage, motor noise and lifetime. They are what we use in our locos.

The CVP BAT2 or BAT3 battery packs are small, lightweight and pack a lot of power into a small package. The BAT2 can power high current motors for a long time. For example, the USA-Trains SD70 will run for more than 3 hours. DO NOT CUT OFF CONNECTOR

With its built-in protection circuitry and its automatic cutoff at the end of the charge, the CVP batteries offer long life, high capacity and nearly constant output voltage over the life of the charge.

The BAT2 dimensions are 2.9 x 2.8 x 1.5 inches (8-cells).

The BATT3 dimensions are 2.75 x 1.46 x 1.46 inches (4-cells).

BAT2 Battery Pack

Low Cost, Universal AC Input, Smart Charger - This charger works off any household line voltage from 90 to 240V 50/60Hz. The built in microprocessor will automatically select the correct charging profile and cut off charging when the battery is fully charged. Indicator lights show red when charging and green with the battery is fully charged. It comes with alligator clip leads. (CHARGER1)

The BAT2 and BAT3 battery packs and the smart charger are available from authorized AirWire Dealers or directly from CVP.

CVP Li-Ion 14.8V Charger

Using Other Batteries and Voltages

Lower Battery Voltage Has Benefits - Lower voltages mean the motors and electronics run cooler. There is also a remarkable increase in effective reception range since lower motor voltage results in less electrical noise. For hilly railroads, consider the use of multiple locomotives on a train. Not only will the batteries have a longer life, but the M60X decoder will run much cooler.

Battery Chemistry and Battery Selection - The more exotic the battery chemistry, the lighter and smaller it will be. The battery will also be more expensive. Always use a battery charger that specifically says it is OK for your battery technology.

Absolute Maximum Input Voltage For The M60X Is 24 volts.

Do Not Exceed 24V When Battery Is Fully Charged - A fully charged battery can be from 2 to 3 volts higher than the voltage rating of the battery. For example, the CVP 14.8V lithium battery pack will read about 16.5 volts to 17 volts when fully charged.

A 22.2V Lithium-Ion battery is the highest rated battery suitable for the M60X. Fully charged, it will be close to the maximum allowed M60X input voltage.

Always get a battery with the built-in protection board. Li-Po batteries usually don't have protection whereas Li-Ion do. CVP's BAT2 and BAT3 are fully protected with a built-in protection board.

See page 24 for more battery information and sources.

Please Read The Battery Safety Datasheet

The safety datasheet that comes with all CVP batteries, discusses dos and don'ts of charging Li-Ion batteries. It also discusses long term storage procedure and requirements.

Battery Hookup And Polarity Verification

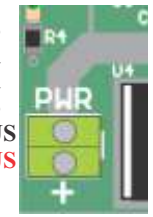
Caution: Installation of the AirWire decoder does not require special tools. However, you should be comfortable with soldering and have a general idea of how your locomotive is wired, as it comes from the factory. If you are at all uneasy about these procedures, your dealer can suggest installers who can do the job for you.

There are three connections to make on your M60X. One for the battery input, one for the motor output and one for the lights. Each of the following sections describes the connection of various terminals on the M60X decoder. Use these diagrams as a generic guide to the connection of the M60X decoder to your locomotive.

Use #20 AWG wire for all battery and motor connections. For improved radio reception, tightly twist two differently colored wires together using an electric drill. Always use two different colors of wire. All naked wires must be insulated with tape and/or heat shrink tubing.

Always include a power switch in every installation. The power switch is used to disconnect the battery from the locomotive and the electronics. A fuse is not needed because the CVP battery contains built-in protection. However, a non-CVP battery may require a fuse to protect the battery against catastrophic failures caused by improper wiring.

Polarity Verification - one way to quickly end the life of the decoder is to connect up the battery with the plus and minus reversed. So we have included polarity testing diode with the M60X decoder is that is used to verify that you have the plus and minus leads properly identified before you connect them to the decoder.



The terminal strip labeled PWR is the battery connection location. The positive lead goes to the terminal labeled + on the circuit board.

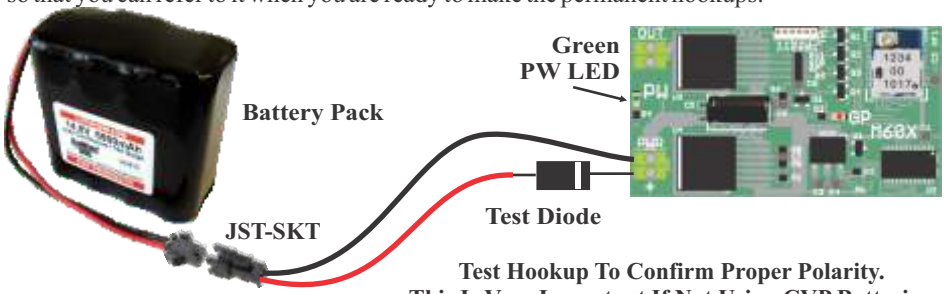
Step 1: Use the JST-SKT pigtail to make connections to the battery. Before plugging the JST-SKT into the battery, make the following connections. Connect the battery minus lead, the black wire, to the decoder's PWR minus terminal (see above).

Step 2: Insert the banded end of the diode into the PWR + terminal and tighten the screw.

Step 3: Insert JST-SKT into the battery. Now touch the battery plus lead, the red wire, to the non-banded end of the diode. If the MX60X bright green LED turns on, then the polarity is correct.

If the green LED does not turn on, something is not correct. There could be a broken wire or perhaps the insulation is preventing the battery's black wire from making proper contact to the terminal strip. It might be dead battery. Regardless, now is the time to find and fix the problem.

Once you have confirmed and identified the proper polarity, mark the wires or make a drawing so that you can refer to it when you are ready to make the permanent hookups.



Test Hookup To Confirm Proper Polarity.
This Is Very Important If Not Using CVP Batteries.

The test diode is not suitable for permanent installation in series with the battery. It can not handle the high motor current and will fail almost instantly.

Simple Troubleshooting Tips

These tips assume the locomotive has been operating normally for a while.

Locomotive Stops Running - But Resumes Running After A Short Rest

This is likely to be caused by overheating of the M60X motor power chip. If the driver overheats, it will automatically shut down. When it cools sufficiently, it will resume normal operation. If this happens, the M60X decoder either needs more ventilation or the motor requires higher current than the decoder can provide. Consider getting a higher current MOTION decoder if you suspect this.

Motor Runs For Short Period Then Stops

There are several possible reasons for this - let's start with the easy one first. Make sure the throttle is turned on, is set to the proper frequency and locomotive address. If all of these are OK, try another throttle. If it too doesn't work, then the cause is the locomotive.

Reconnect the charger and verify that the charger indicator is visible and green. If the light is red, then the battery is depleted and needs to be recharged.

Finally, it is possible that a momentary overload tripped the battery protection circuits. Cycle the decoder power off then back on and try again. If the problem persists, there may be problem with the battery. Or it could be as simple as a broken wire. You need to disassemble the locomotive to check these items.

Throttle Looses Control When Locomotive Is Far Away

This is just the normal limitation of the radio system. Do not expect the throttle to control the train when it is a thousand yards away. However, if your railroad is in a large loop, then leave the throttle on its original setting and let the train come back to you. Once the train is within range, the throttle will once again regain control.

Using The M60X Red And Green LEDs

The M60X red and green LED indicators can help pinpoint many issues.

The Green LED is the power indicator LED. It will be glowing bright green when power is applied. If the LED is not lit, suspect a dead battery or broken connections somewhere between the battery and the decoder.

If the **Green LED** dims or flickers when the locomotive is moving, the battery is weak and either needs to be charged or replaced.

The **Red LED** has several functions. When the decoder is receiving AirWire throttle information on its assigned frequency, it will be on solid red. To double check, turn off the throttle. The red LED will go dark and then start flashing about once per second.

If the **Red LED** is on without a throttle turned on, then there is some kind of internal fault in the AirWire decoder and it will need to be sent in for repair.

If the **Red LED** never flashes, or never turns on, there is some kind of internal fault in the AirWire decoder and it will need to be sent in for repair.

If the **Red LED** is flashing with or without a throttle turned on, the decoder is programmed to a different frequency than what is set in the throttle. Set the throttle to the correct frequency. If you are not sure of the frequency, use the "lost frequency" method to reset the decoder to the desired frequency. See page 9 for how to recover from the "forgotton frequency" problem

If the **Red LED** is on when the throttle is on, and off when the throttle is off, the decoder and the throttle frequencies match. But if the motor doesn't respond, then the decoder and throttle loco numbers don't match. Reprogram the decoder to the desired loco number.

M60X Cruise Control

The M60X decoder comes equipped with a convenient cruise control design for maintaining the speed of a locomotive. Just like the cruise control in an automobile, once activated the locomotive will maintain the same average speed independent of the load or the terrain of your layout. It will cruise up hill and down hill as well as snake through tight curves and turnouts while maintaining the same average speed automatically without user's intervention.

Activating Cruise Control is done with Function 5 which is the original factory setting for cruise control activation. From the decoder action table, a value of 1 is the cruise activation value and it is set into CV39 [F5]. If wanted, you can change the function key assignment at any time.

Two Types Of Cruise Control Are Selected By CV63.

Cruise mode 0 is the original factory setting with a value of 0 in CV63. In this mode, the locomotive speed is held at whatever it was when cruise control was activated. But, if the throttle speed is changed, up or down, or the direction is reversed, the cruise control is deactivated. Mode 0 is easy to use. Once the train reaches the desired speed, push F5 (or what ever key you have assigned to activate cruise control) to enable cruise.

Cruise mode-1 is selected by setting CV63 to a value of 1. With this mode, the locomotive speed can be adjusted higher or lower without deactivating cruise. Setting the throttle to speed 0 or reversing the direction will deactivate cruise control.

Operational Considerations

Beware of Lurking Locomotives When Using SERVICE PROGRAM Mode
SERVICE PROGRAM mode is a broadcast command that can be heard and understood by any other decoder sharing the same frequency as the intended decoder. If another decoder receives the command, it too will be programmed. Play it safe and make sure to turn off all power switches on locomotives not being programmed.

Beware of Other Transmitters
The M60X decoder operates in an unlicenced band shared by many other transmitters. These transmitters can and will create interference, intermittent throttle operation or complete failure of one or more of your decoder's 17 frequencies. The sources of these external interfering signals can be from your own home or from adjacent homes and businesses. They can also be from other CVP wireless throttles and controllers.

Here's a list of devices known to have caused interference problems to AirWire900 equipment: wireless devices attached to computers, TV/Radio/Entertainment-center, remote controls, cordless telephones, alarm systems, baby monitors, unlicenced personal communication devices, lawn sprinkler controllers, remote starter switches, cordless light switches, outdoor lighting controllers, toys, wireless headphones, and games. Of course, if you have additional wireless throttles, make sure each is on its own frequency. Two throttles on the same frequency will jam each other.

If you find a strong interfering signal on one or more of your frequencies, don't use those frequencies. Simply select another, different frequency.

Never Use Glue, RTV or Silicon Adhesive On The M60X
NEVER use glue, RTV or other liquid adhesive to attach the M60X to the locomotive. That material is conductive and will destroy the decoder. Use only double-sided tape.

Decoder Placement Suggestion For Best Range
If possible, mount the decoder horizontally and as high as possible within the locomotive. If you are using the M60X with a whip antenna, a vertical antenna may offer better range although you should also try horizontal. Keep the whip antenna away from motor and battery wiring as much as possible. Never let it touch anything metal. For metal locomotives, the need for an external antenna becomes very important. CVP offers some external antennas that use the same socket as the whip antenna. See the CVP website for details.

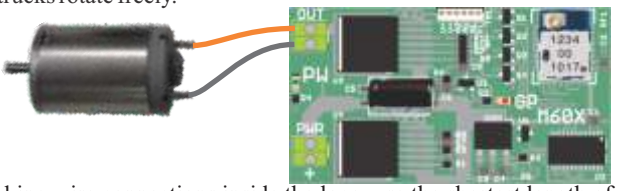
Motor Hookup

"OUT" Terminal Strip

The terminal strip labeled OUT is where motor wires are connected. locomotive motor. Use stranded wire to make connections. For best noise suppression, twist the two motor wires together. Always tin the wire before inserting it into the terminal strip.

When inserting the stripped and tinned wire, the bare wire should be just barely visible outside the terminal clamp. If you can't see the bare wire, the clamp might contact the insulation resulting in poor connection. If the bare wire is too long, it might short out adjacent wires. Fasten the wires out of the way and make sure the locomotive trucks rotate freely.

This is a generic motor image. Your motor may be embedded in a truck or chassis. Make sure no other circuit boards are connected to the terminals of the motor.



Neat wiring is a must: When making wire connections inside the loco, use the shortest length of wire that will do the job. After the wires are attached and insulated with heat shrink sleeving, secure them so that repeated removal and replacement of the locomotive shell won't pull the wires loose. The biggest cause of decoder failure after initial installation is wires being pulled loose and shorted to the frame when the shell is removed or replaced.

Incorrect operation of the constant speed feature will occur if there is other circuitry, including lighting circuit boards, connected to the OUT terminals. Only motors can connect to the OUT terminals.

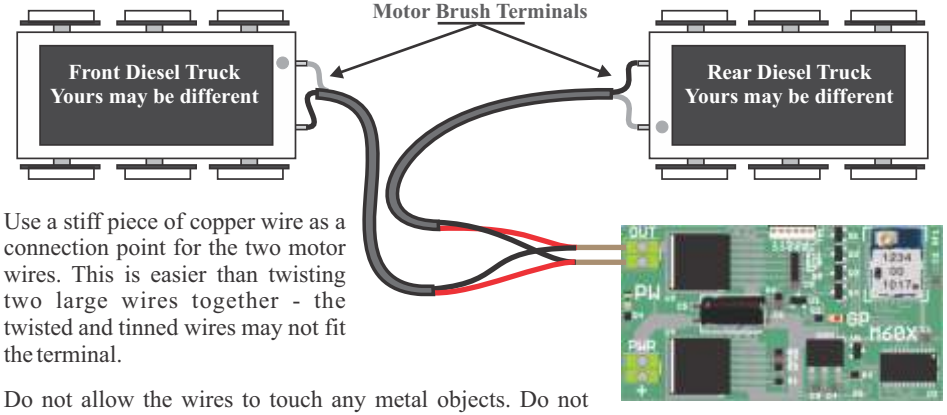
Locomotives with Two Motors

The only difficulty with two motors is that you might accidentally hook one of them up backwards. Before closing up the locomotive, verify that the motors are both going in the correct direction. As shown in the drawing, most manufacturers will label one motor terminal with a colored dot for reference.

Locos with two motor trucks usually reverse one truck. That is why the motor wires are crossed in the hookup diagram.

Before closing up the locomotive, be sure to test that the motors both go in the same direction. Should you find one motor going the wrong direction, reverse the wires on the appropriate motor.

The AirWire throttle convention is forward when the direction points to the right. Set throttle for forward and check the loco is moving forward.



Use a stiff piece of copper wire as a connection point for the two motor wires. This is easier than twisting two large wires together - the twisted and tinned wires may not fit the terminal.

Do not allow the wires to touch any metal objects. Do not allow the motor wires to short together.

Motor Hookup *continued*

Disconnect Track Pickups
The locomotive track pickup contacts and wiring **must be** disconnected and removed before hooking up the decoder.

If the track pickups are not removed, there is a risk that the onboard battery voltage may appear on the track pickups and thus on the rails. Any subsequent derailments or external applied track power will short out and destroy the battery.

Beware Of Motors That Connect To The Chassis
Older locomotives designed prior to the DCC-era usually have one of the motor brushes connections tied to the frame using a screw or a spring. If not isolated, the decoder's motor output or it will short circuit to the frame and/or the rails through the track pickups when connected to the motor.

Lighting Hookup - *Not Yet!*

The M60X offers many exciting lighting features and options from which to select. Lighting hookup, options and setup will be discussed in great detail starting on page 10.

However, at this point in the installation, it is a good idea to perform a check to confirm the motor and battery are properly connected and run in the correct direction.

Initial M60X Decoder Checkout

The initial decoder checkout assumes you have either installed your new M60X decoder, or are testing it on the bench. For the initial checkout, it is assumed that the M60X has not been changed and is on the original factory settings of loco address 3 and frequency 0.

Step 1: Turn on your AirWire throttle.
Set it for loco address 3 and frequency 0. These are the original factory settings for the M60X decoder.

Step 2: Turn Power on to the M60X Decoder
The M60X's green LED will glow brightly indicating power is connected.

When the throttle is turned on and set to the same frequency as the M60X decoder's red GP LED will glow brightly. If the red LED is not on, then your throttle is not set properly. Do not proceed to step 2 until the red and green LEDs are turned on and glowing steady.

Step 3: Set the Throttle and Run!
Set the desired direction and turn up the speed knob to run your locomotive. The right facing arrow is FORWARD as if you were seated in the cab.

If the loco movement direction is backward, reverse the motor wires.

The concludes the initial testing. The next section describes how to set or change the M60X loco address and its frequency.

Setting Decoder Locomotive Number (address)

If you need to program the locomotive number (address), use the following keystroke sequence on a programming throttle like the T6000 (used in the steps below) or the older T5000.

Tip: Use the locomotive cab number as the locomotive decoder address.

- Press the green MENU key once;
- Press and hold the green ENT key. Release the key when the menu page 1 appears;
- Press the green MENU key once again. Menu page 2 appears;
- Press the 4 key (SVC PROGRAM) to show the CV number entry screen;
- Press the 1 key followed by the ENT key; CV1 stores the loco address.
- Press the number keys for the desired loco number; range is 1 to 9999.
- Press the ENT key. The locomotive will jump indicating it received the command.
- Push the ESC key. The new loco number will be present on throttle's screen.

Locomotive Speed Matching Tips - *continued*

Basic Procedure: Lower the target CV value by 10% increments. For example, CV6 has a factory default value of 128 so a 10% reduction is equal to about 115. Now shut of all locos except the one to be change. Use SVC PROGRAM to change CV6 to the new value. Restore power to the other locos and evaluate the result. If the loco is still too fast, lower it another 10%.

Tip: Always have a slight amount of tension on the locomotive couplers. This will keep them from uncoupling over rough track and prevent jerky operation. Thus, the locomotives will not be perfectly matched - the lead loco should be slightly pulling on the trailing locos when running in the forward direction. However, the lead loco should never be dragging the trailing locos. Likewise, the trailing locomotives should not be pushing hard the lead loco. A small amount of coupler tension will make the individual locos run together as if they were a single unit.

Use SVC PROGRAM Only

Step 1: Match locomotives at step 14 [CV6 - factory setting 128]

Using the slower locomotive as reference, lower the value of CV6 to slow down the faster locomotive to match the speed of the slower locomotive with the throttle set at speed step 14. When the two locos are relatively close in speed, you are done. Make a note of the value used.

Step 2: Match locomotives at top speed [CV5 - factor setting of 255]

Using the slower locomotive as reference, lower the value of CV5 to slow down the faster locomotive to match the speed of the slower locomotive with the throttle set at speed step 28. When the two locos are relatively close in speed, you are done. Make a note of the value used.

Step #3: Fine tuning the low speed setting only (2 methods).

Using the slower locomotive as reference, compare the speed of both locomotives at speed step 7 (middle of the low speed setting). If both locomotives are running at more or less the same speed then no fine tuning is necessary. If not then fine tuning the low speed setting may be done next. There are two ways, using CV6 or CV2 only.

Using CV6 is the first method and results in minor speed differences at step 14. Reference locomotive is running slower at speed step 7: lower CV6 of the other locomotive to match the speed of the reference. Conversely, if the reference locomotive is running faster at speed step 7, then increase CV6 of the other locomotive to match the speed of the reference.

Using CV2 is the alternative method and results in minor speed difference at step 1. Reference locomotive is running slower at speed step 7: lower CV2 of the other locomotive to match the speed of the reference. Conversely, if the reference locomotive is running faster at speed step 21, then increase CV2 of the other locomotive to match the speed of the reference.

Lipstick On A Pig

None of the fine tuning techniques will compensate for an old, worn out, out-of-gauge or dirty locomotive mechanism. Take some time to clean and lubricate the mechanism. Verify the gauge of the wheels. It will be time well spent.

Fine Tuning Slow Speed Operation With Bumping

Many users assume that CV2 is used to control how the locomotive starts up at slow speeds. However, you should not use CV2 for that purpose. Instead take advantage of the advanced M60X feature of motor bumping. The bumping feature can be used along with the ultra high resolution speed curve created with CV2, CV5 and CV6.

With motor bumping, you can achieve silky smooth performance at very low speeds. There are two CVs for this feature, the motor bump value, CV56 and the motor bump duration, CV57. Your M60X will automatically transition from the slow-speed bump to the high resolution speed curve operation as the locomotive gains speed.

Motor Bump Value is Set With CV56. The value sets the amount of momentary motor voltage increase, called a bump, applied at each speed step to the help motor overcome friction. It helps get the motor rotating at a lower voltage and/or a lower speed step. Once the locomotive is moving, the bump automatically goes away. A value of 0 disables the motor bump and is the original factory value. A value of 128 will literally apply half of full speed to the motor.

Motor Bump Duration is Set With CV57. This value selects the duration of time that the bump value is applied when the bump is active. A value of 0 disables the bump completely, no matter what is set in CV56. The original factory setting is 0.

Experimenting With Motor Bumping

To use the motor bump feature, the following procedure is recommended.

Step 1: Set the throttle to speed step 1 and observe the locomotive's wheels. They may or may not be turning.

Step 2: Set CV56 to a value of 15 and CV57 to a value of 50. Observe the locomotive wheels and see if they are now turning. Stop and then return the throttle to step 1. Look for consistent forward motion and make sure that the bump is sufficient for smooth operation over the entire length of the track at speed step 1.

Step 3: If the wheels are not yet turning, increase either CV56 or CV57 or both by a value of 5 and check again. You should make changes to the CV values in increments of 5. Smaller increments may not cause any noticeable changes.

There is a tradeoff between the bump value and the bump duration. If a small bump value is applied, then a longer bump duration will be needed. Or, if a large bump value is used, it can be applied for a shorter duration .

Careful choices of CV56 and CV57 will give not only fine control at slow speeds but allow the full range of precision speed control over the entire speed curve. Think of the motor bump as an added feature that provides an extra boost of energy to get the locomotive moving at low speeds.

Locomotive Speed Matching Tips

Using CV2, CV6 and CV5, you can match the speeds of two or more different locomotives. One important consideration is to determine which locomotive in a consist is the slowest. It is to this slow locomotive that you will match the other members of the consist. Always match a locomotive to the slowest member of the consist since we cannot make a slow locomotive run faster than its top speed. The following examples illustrate some of the possible ways to match up locomotives.

You may find that matching locomotives at the top and mid point speeds is close enough. By all means you may stop if you are happy with the performance after steps 1 and 2. The procedures below allow you to precisely match locomotive speeds at all speed steps, not just two. The penalty is a bit more time but you will be impressed with the results.

Since Service Mode Must Be Used, Take Care To Program Only One Locomotive

Turn Off All Other Locomotives To Avoid Unwanted Changes.

continued on next page

Changing The M60X Decoder Frequency

As delivered, the M60X is set to frequency 0. If you want to use a different frequency, follow the series of steps below. For easier remembering, select a frequency derived from the loco number. For example, use the first digit or the last digit of the cab number. This makes it easy to remember what frequency the loco is using.

The procedure below uses the **SVC PROGRAM** mode of your programming throttle. A T6000 is used for this example. Verify that all other locos sharing the same frequency are turned off or they too will be changed.

- Press MENU
- Press and Hold ENT
- Press MENU again to get to page 2 of the options.
- Press 4 (SVC PROGRAM) to show the CV entry screen.
- Press 2,0,0, ENT which is the CV number that stores the frequency number.
- Press the number keys to enter the desired frequency Then press ENT. The frequency range is from 0 to 16. The moment ENT is pressed the locomotive will jump indicating it received the programming command.
- Press ESC to end programming. The throttle is automatically set for the new frequency.

Forgotten Frequency? - Resetting M60X Frequency

There may come a time when the M60X no longer responds to what you believe is the correct frequency, or you can not remember the correct frequency. If this occurs, follow this procedure called the "Jump Mode." This feature will temporarily force the M60X to frequency 0 where you can make a permanent frequency change.

Warning: make sure there are no powered on locomotives assigned to frequency 0 or they too will have their frequency changed.

- Turn off all AirWire throttles. This is very important.
- If the locomotive power is on, turn it off. Count to 10. Now turn on the locomotive power.
- Wait a minimum of 60 seconds before continuing. Longer is OK.
- Turn on your throttle. Make sure it is set to frequency 0.
- Use SVC PROGRAM to set CV200 to the desired frequency. The locomotive will jump when the command is received.
- Push ESC to end programming.

Resetting M60X To Original Factory Settings

CV8 is used to reset the M60X back to original factory settings of loco address 3 and frequency 0. Use a programming throttle like the T6000 or T5000. Set the throttle to the same frequency as the M60X.

- Press MENU
- Press and Hold ENT
- Press MENU again to get to page 2 of the options.
- Press 4 (SVC PROGRAM) to show the CV entry screen.
- Press 8, ENT which is the CV number that allows reset.
- Press 1,3,5 and ENT. The moment ENT is pressed the locomotive .
- Press ESC to end programming.

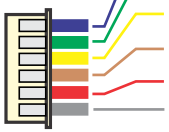
Changing The Throttle's Frequency or Number Doesn't Change The Decoder!

Simply changing the throttle's frequency or the throttle's loco number will not change the decoder in any way! The decoder must be ***programmed*** with SVC PROGRAM.

Headlight Hookups

The locomotive lights connect to the M60X via a wire harness that plugs into the TM1 socket. The plug makes it easy to connect and disconnect the light wiring.

There are a total of 4 light output wires. There are also 2 wires that connect back to the BAT+ terminal.



LED Driver Outputs

V+	Battery Voltage Source
V+	Battery Voltage Source
A2	A2 Light Driver
A1	A1 Light Driver
RL	Rear Light Driver
FL	Front Light Driver

Either one of the two V+ wires can be used.

A1 and A2 are additional light drivers.

A1 and A2 can be configured to work together to provide a ditch light effect. Or they can be configured to be independent of each other.

RL is the rear headlight driver.

FL is the front headlight driver.

Unused wires can be clipped short and discarded.

The harness wire is stranded #30AWG which is easily stripped with your fingernails. Always tin the stripped ends of the wires. Twist the strands together and apply a small amount of solder to the twisted wires. Tinning and keeps the wires from fraying. Don't allow wires to touch other components or each other or the M60X board.

If you cut wires too short or make a mistake, a replacement harness can be ordered from CVP. Ask for part number ALT6.

Using The Headlight Output Drivers

The M60X light drivers are designed to use low current, cool and bright white, light emitting diodes (LED). You can use incandescent lamp in place of an LED but it will run the battery down quicker and appear dimmer. Also, the special lighting effects will not appear as nice as they do when using an LED. For the remainder of the examples, LEDs will be used.

Light outputs are not protected. The light driver outputs have a maximum current rating of 1 Amp. They can burn out if overloaded. Multiple lights may be powered from a light driver output as long as the maximum current rating is not exceeded.

LEDs are Polarized Long Lead is "A" or anode

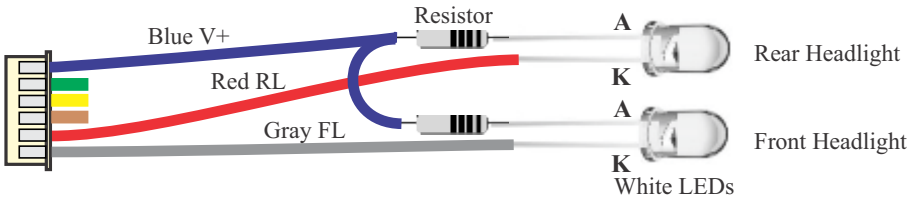
Example LED Hookup

For this example, the forward and reverse headlights will be connected to white LEDs. No other wires will be used.

The diagram of the lighting harness shows the front headlight (FL) to be the gray wire. The rear headlight (RL) is the red wire. The source voltage (V+) will come from the blue wire.

If no other wires are to be used, cut them close to the socket. Determine the desired length of the two wires.

Always cover and insulate all wire joints. No bare wires!



Resistor value depends on battery voltage - see next page

Motor Acceleration and Deceleration Control

Locomotive inertia is the rate at which a locomotive accelerates when changing from a slow speed to a higher speed. Locomotive momentum is the rate at which a locomotive decelerates from a high speed to a lower speed. Inertia and Momentum are simulated by values in CV3 and CV4. The values change how the locomotive responds to throttle speed changed.

Motor Acceleration Rate (Inertia) is Set With CV3. CV3 deals with the rate of acceleration when the throttle speed is increased. In other words how quickly does the operator intend for the locomotive to accelerate. The smaller the value of CV3 the quicker a locomotive will accelerate. The original factory setting is a value of 2 which provides for a relatively quick response to speed increases.

In most cases, users prefer a *slower* rate of change for the acceleration rate. Common values are 3, 4 and 5. Large values result in extremely long delays for speed changes to take effect which are usually uncomfortable for users - they think something is wrong with the locomotive. The acceleration rate applies equally in either the forward or reverse direction.

Motor Deceleration Rate (Momentum) is Set With CV4. This CV sets the rate of change of speed upon when the throttle speed is decreased. This is called the deceleration rate. Small values mean the rate of change is faster. A higher value leads to a slower rate of change. The original factory setting is a value of 2 which provides for a relatively quick response to speed decreases.

Surprisingly most users prefer a *faster* deceleration rate compared to the acceleration rate. High values will result in extremely long delays for locomotives to slow down. If you imagine your favorite locomotive speeding towards another train, you will want to be able to quickly stop the train. This is why the original factory setting of 2 is seldom changed. Users want to slowly start the train, but quickly stop it. The deceleration value applies equally in either the forward or reverse direction.

Beware Of Large Values For CV3 and CV4

Large values for acceleration or deceleration rates will result in very slow response to throttle changes. Extreme values will result in the locomotive never starting, or, never stopping - neither of which is very uncomfortable.

New Motors Should Be Broken In Before Using

A new motor usually doesn't have motor brushes that conform well to the circular shaft of the commutator. The brushes tend to draw more than normal current, and exhibit arcing. As a result, the motor causes lots of radio noise that will result in less reception range. To prevent this from occurring, just run the motor for an hour or so at full speed and in each direction. This will seat the motor brushes and greatly reduce radio noise generation.

Locomotive Motion Control and Fine Tuning *continued*

Customizing The Speed Curve To Your Requirements
Customizing a speed curve is easily done by modifying one or more of the three configuration variables. It helps to visualize the speed curve as having two separate halves as shown in the graph with the split at the 50% throttle speed position. The left half is controlled by CV2 and CV6 and responds to the first 14 speed steps (in the 28 speed step setting). The right half is controlled by CV6 and CV5 and responds to speed steps 15 to 28 (in the 28 speed step setting).

I want finer slow speed control: With CV2 and CV5 unchanged, the step size of speed steps 0 to 14 in the left half of the speed curve can be reduced to give finer control by simply reducing the value of CV6 from the default 128 to a smaller value. For example, by reducing CV6 to 100, each of the 14 steps will be reduced by a value of 2. As a result of reducing CV6 to 100, the step size for speed steps from 15 to 28 in the right half of the speed curve increase by a value of 2. The result is curve #2. Thus, you gain finer speed control at the low end of the throttle range at the expense of bigger steps at the high end. For yard operations, you will find this setting to offer precision slow speed control right when you needed it.

I want finer high speed control: With CV2 and CV5 unchanged, the step size of speed steps 15 to 28 in the right half of the speed curve can be reduced to give finer control by simply increasing the value of CV6 from the default 128 to a larger value. For example, by increasing CV6 to 156, each of the 14 steps will be increased by a value of 2. The result is curve #4. It is important to remember that as a result of increasing CV6 to 156, the step size for steps 0 to 14 in the left half of the speed curve would be increased by a value of 2.

I want both finer speed steps for slow and high speed control: With CV2 unchanged, the step size of speed steps 0 to 28 can be reduced to give finer control by simultaneously reducing the values of CV6 and CV5 to a smaller value. For example, by reducing CV6 from a default of 128 to 100, and CV5 from a default of 255 to 227, the step size for the entire speed curve is now reduced by a value of 2 to give finer control. The result is curve # 3. By reducing CV5 to a smaller value, the top speed at the high end is lower which will result in less torque at high throttle settings.

CV2 has remained unchanged in the above examples. The next set of examples, shows what you can do by modifying CV2. These are not graphed but are discussed to show that you can create an unlimited variety of speed curves using just 3 different CVs.

I want a higher MSV with finer slow and high speed control: With CV5 unchanged, the step size of speed steps 0 to 28 can be reduced to give finer control by simultaneously increasing the values of CV2 and CV6 to a larger value. For example, by increasing CV2 from a default of 9 to 37, and CV6 from a default of 128 to 156, the step size for the entire speed curve is now reduced by a value of 2 to give finer control. By increasing CV2 to a larger value, the MSV is now higher for the low end starting speed of speed step 1.

I want higher MSV and reduced top speed with finer slow and high speed control: With CV6 unchanged, the step size of speed steps 0 to 28 can be reduced to give finer control by simultaneously increasing CV2 to a larger value and reducing CV5 to a smaller value. For example, by increasing CV2 from a default of 9 to 37, and reducing CV5 from a default of 255 to 227, the step size for the entire speed curve is now reduced by a value of 2 to give finer control. This also results in a reduced top speed at speed step 28 and an increased starting speed at speed step 1.

LED Limit Resistor Selection

The LED must always be used with a series limit resistor or they will instantly burn out and burn out the driver. The value of the limit resistor depends on the battery voltage, the LED color and the desired brightness. The LED color dictates the average voltage drop across the LED which is called VF. White LEDs have the highest VF, at about 3 volts.

White LEDs are at full brightness between current values of between 10mA (0.01A) and 20mA (0.02A). A lower current will lengthen the battery life. Their VF is about 3.1V.

Colored LEDs have different VF values. Red is about 1 volt VF. Green and yellow are about 2 volts VF. Use the same current rating to determine the initial limit resistor. Experiment with different resistor values to achieve the desired brightness.

To determine the required resistor value, use the equation below or the table. The table below shows LEDs versus battery voltage and the resulting resistor value for 20mA through the LED.

R (in ohms) = [Battery Voltage] - [LED voltage VF] divided by [desired current in Amps]

LED Color	BAT+	LED VF	Current(A)	Value	Closest R	Power Rating
White	14.8V	3.1	0.02	585	560	eighth watt
Green/Yellow	14.8V	2.1	0.02	635	620	eighth watt
Red	14.8V	1.0	0.02	690	680	eighth watt

Standard 5% Resistor Values (1st 3 numbers)											
100	110	120	130	150	160	180	200	220	240	270	300
330	360	390	430	470	510	560	620	680	750	810	910

More LED Hookup Options

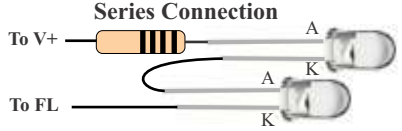
Series Hookup of LEDs
LEDs can be connected in series, one connected to the other. A common application is when a locomotive has a dual-beam headlight.

Since the LEDs are in series, they each get the same current which is 0.02A. However, since two LEDs are in series, calculating the resistor requires that 2 times the LED-VF value be used (3.1 x 2 = 6.2).

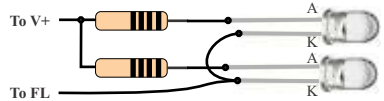
The table below shows the new resistor value for two LEDs in series vs battery voltage.

LED Color	BAT+	LED VF	Current(A)	Value	Closest R	Power Rating
White	14.8V	3.1 x 2	0.02	430	430	eighth watt

Series Connection



Parallel Connection



Parallel Hookup of LEDs
LEDs can be connected in parallel. The only difference is that each LED must have its own limit resistor. Otherwise, they will not share the current equally resulting in different brightness for each one.

For parallel LEDs, the series resistor will be the same value as if there was only a single LED. Unlike the series calculation, a single VF value is used. For this example, the resistor value is 560 ohms.

Customizing Headlight Operation

The M60X Decoder allows the front headlight and the rear backup light to operate in different modes. The different modes control if and when the headlight dims and how the front headlight and rear headlight change with locomotive direction.

The Headlight Mode options is determined by the value of CV60. Use SVC PROGRAM mode to set CV60 to the desired value.

Normal Operation (original factory setting): The original factory setting for CV60 is a value of 0. This means that the front headlight is on and the rear headlight is off when the locomotive is moving in the forward direction. When the direction control is set for reverse, the rear headlight turns on and the front headlight turns off.

Auto-Dim Headlight Mode [rule 17]: When this option is selected, the headlight automatically dims when the throttle is set to zero speed. When dimmed, the headlight glows at a reduced brightness and without any special effects. Turning up the speed knob automatically restores the headlight and its assigned lighting effect to full brightness. This feature is optimized for white LEDs. Locomotives that use incandescent bulbs for headlights may appear very dim when using this feature.

CV Value	CV60 Headlight Mode
0	Normal Autoreverse
1	Normal with rule 17
2	Front headlight always on
3	Front headlight always on w/rule 17
4	Rear headlight always on
5	Rear headlight always on w/rule 17
6	Front and rear headlights always on
7	Front and rear headlights always on w/rule 17
8	Swap F to R Autoreverse
9	Swap F to R Autoreverse w/rule 17
10-15	Reserved

The table lists the mode and the corresponding CV value for CV60. Experiment with the various modes and select the one that you like the best.

Headlight Mode Example: Front Headlight With Auto-Dimming

CV60 is used to change the operating mode of the front and rear headlights. Auto-dimming is a headlight operating mode that means that when the locomotive speed command is zero, the headlights will automatically dim.

Also, if there is an effect applied to the headlight, it will be turned off. The moment the speed is increased, the headlight comes on at full brightness and with whatever effect is active. For this example, set CV60 to a value of 1. This value sets up normal, auto-reversing headlight operation except when the locomotive is stopped. When stopped, the headlight will automatically dim.

Head Lights Are Turned On With F0

F0 is shorthand for throttle function key 0. To turn headlights on or off the headlights, push the 0 key on your throttle.

Lights Are Normally Off

When the M60X decoder is powered up, all lights are off.

Locomotive Motion Control and Fine Tuning

There are 3 CVs that determine how the locomotive motor responds to a throttle speed command. Following the NMRA-DCC standard, these are: CV2 (Vstart or motor-starting-voltage MSV) CV6 (Vmid), and CV5 (Vmax). The full scale motor voltage value ranges from 0 to 255 so these 3 CVs also have a value range of 0 to 255. You may set these values to suit your desired locomotive performance as well as to help with speed matching of different locomotives.

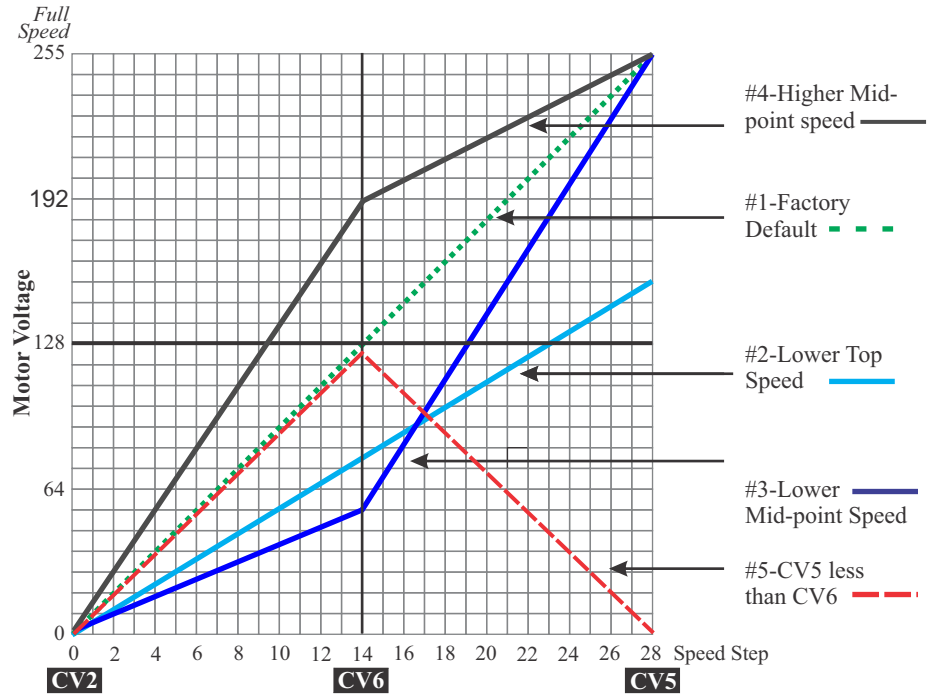
Motor Starting Voltage Value (MSV) is Set With CV2 . CV2 sets the MSV of the motor voltage that corresponds to speed step 1 (in a 28 speed step setting). The original factory value is 9. You can decide if you wish the motor to be moving at a good rate of speed or just barely moving by changing the MSV. A small MSV value means only a small extra increase in motor voltage. A larger MSV value means the motor receives a higher motor voltage.

Mid-point Motor Voltage Value (Vmid) is Set With CV6. The mid-point voltage is the motor speed when the throttle is at half of full speed which is speed step 14 when the throttle is set for 28 speed step setting. CV6 is used to set the motor voltage with 128 being the factory default value which is exactly half way between 0 and 255. If a lower half speed is needed, for example in speed matching application, set CV6 to a smaller value.

Maximum Motor Voltage Value (Vmax) is set with CV5. The top speed voltage (full speed) corresponds to speed step 28 when the throttle is set for 28 speed step setting. CV5 is used to set this voltage and 255 is the factory default. If a lower top speed is needed, for example in speed matching application, set CV5 to a smaller value. Speed curve #2 lowers the top speed to 155. So at speed step 28, the locomotive is running at 60% of the maximum motor voltage. It should be noted that every speed step from 1 to 28 will be slower accordingly.

Setting CV5 to a value less than CV6 is OK but the resultant speed curve will be an upside down V. Curve #5 shows the extreme case with CV5 equal 0 and CV6 equal to 128, The motor will reach top speed at step 14 and then gradually slow down to a stop at step 28.

The graph below shows the relationship of the 3 CVs and how they affect the motor speed.



Special Lighting Effects For A1 and A2 Drivers

Similar to the headlight effects, the A1 and A2 LED outputs can be given a variety of special lighting effects. The effects can be different on each AUX output. For effects that have a repeating pattern, another CV is used to set the timing which is shared by the effects assigned to A1 and A2.

A1 Special Light Effect Value Is Stored in CV48: The original factory value is 2. This means that A1 turns on to full brightness when activated.

A2 Special Light Effect Value Is Stored in CV49: The original factory value is 2. This means that A2 turns on to full brightness when activated.

Effects That Utilize A Specific Time Period or Rate use the value in CV47 to set the time multiplied by ½ second. The original factory setting is a value of 3 which sets the interval at 1.5 seconds. The rate or time affects the lighting effects that offer a repeating pattern. The range for CV47 is 1 to 15 and is in units of 1/2 second. For example a period value of 2 gives a repeating pattern of about once per second. Bigger numbers represent slower repeat times. A value of 0 shouldn't be used although if you accidentally enter 0, the uAWM60X will automatically change it to a value of 1.

Special Lighting Effects List: The table lists the lighting effects and the CV value to select the lighting effect. Also shown is whether CV47, the timing rate, applies to these effects. All of these effects are optimized for LED lighting.

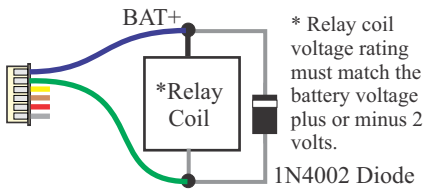
CV Value	A1 & A2 Lighting Effects [CV47, CV48, CV49]	
0	OFF 0%	
1	Dim 6%	
2	Dim 25%	
3	Dim 50%	
4	ON 100%	
5	Strato Light	[rate set by CV59]
6	Oscillating Light	[rate set by CV59]
7	FRED	[rate set by CV59]
8	Rotary Dome Light 1	[rate set by CV59]
9	Gyra Light	[rate set by CV59]
10	Mars Light	[rate set by CV59]
11	Rotary Dome Light 2	[rate set by CV59]
12	Strobe Single Pulse	[rate set by CV59]
13	Strobe Double Pulse	[rate set by CV59]
14	reserved	
15	Random Flicker	

An effect labeled "reserved," means the value can be set into a CV, and the motor will pulse. But, if activated, nothing will happen.

Lighting Effects Not Available for A1/A2 When Used In Ditch Light Mode

The lighting effects do not apply when A1 and A2 are configured as ditch lights. When configured as ditch lights, the two outputs will alternately fade in and fade out just like real ditch lights. When not flashing, the ditch lights turn on along with the headlights when F0 is activated.

Hooking Up A Relay Instead Of An LED



A relay or a solenoid can be driven by the A1 or A2 outputs (A2 shown). Be sure the relay coil voltage rating is close to the battery voltage.

Always install a diode across the relay or solenoid coil. The banded end connects to the relay coil that connects to the battery plus wire. The diode's other end goes to the relay coil that connects to the LED driver.

Use the diode that was included with your M60X.

Special Headlight Effects

In addition to how the headlights react to direction changes, each headlight can have a special lighting effect assigned to it. For example, you can set the rear headlight to always be dim whenever it is turned on. Simulated gyra lights can also be assigned to headlights.

Front Headlight Effect is stored in CV61. The original factory setting is a value of 2 which means the front headlight is on at 100% brightness when activated.

Rear Headlight Effect is stored in CV62. The original factory setting is a value of 2 which means the rear headlight is on at 100% brightness when activated.

Effects That Utilize Specific Time Period or Rate use the value in CV59 to set the time multiplied by ½ second. The original factory setting is a value of 3 which sets the interval at 1.5 seconds. The rate or time affects the lighting effects that offer a repeating pattern.

The range for CV59 is 1 to 15 and is in units of 1/2 second. For example a period value of 2 gives a repeating pattern of about once per second. Bigger numbers represent slower repeat times. A value of 0 shouldn't be used although if you accidentally enter 0, the M60X will automatically change it to a value of 1.

Special Lighting Effects: The table lists all lighting effects and the CV value to select the lighting effect. Also shown is whether CV59, the timing rate, applies to these effects.

All of these effects are optimized for LED lighting.

CV Value	CV61 & CV62 Headlight Effects	
0	OFF 0%	
1	Dim 6%	
2	Dim 25%	
3	Dim 50%	
4	ON 100%	
5	Strato Light	[rate set by CV59]
6	Oscillating Light	[rate set by CV59]
7	FRED	[rate set by CV59]
8	Rotary Dome Light 1	[rate set by CV59]
9	Gyra Light	[rate set by CV59]
10	Mars Light	[rate set by CV59]
11	Rotary Dome Light 2	[rate set by CV59]
12	Strobe Single Pulse	[rate set by CV59]
13	Strobe Double Pulse	[rate set by CV59]
14	reserved	
15	Random Flicker	

Headlight Lighting Effects Examples and Tips

Front Headlight With Mars Light: First, look up the value for CV61 to implement the Mars light. From the above table the value is 10. Use SVC PROGRAM to load the value of 10 into CV61. Note that CV61 only applies to the front headlight. If the locomotive direction set to reverse, the front headlight goes out and the rear headlight turns on steady at 100% brightness.

Multi-Unit Consist With Directional Lighting For Leading and Trailing Units

In this example, there are 3 locomotives that are consisted together at the throttle. Each locomotive has a M60X decoder. The locomotives all face the same direction. The desire is for the lead unit to have the front headlights on, when in the forward direction and its rear headlight off when going in the reverse direction. For the trailing unit, only the rear headlight is on when going in the reverse direction and the front headlight is off when going forward. The middle unit has both headlights turned off. The CV numbers and their values are shown for the leading and trailing locomotives. All locomotives share the same frequency.

Leading Locomotive	CV#	Value	Trailing Locomotive	CV#	Value
Headlight Mode	CV60	0	Headlight Mode	CV60	0
Front Headlight Effect	CV61	2	Front Headlight Effect	CV61	0
Rear Headlight Effect	CV62	0	Rear Headlight Effect	CV62	2

Assigning Throttle Function Keys To M60X Actions

The M60X decoder has many memory locations so we use the term CV# where # is a specific memory location. So CV40 means decoder memory location number 40. The value stored at this location dictates what action the decoder does when it receives a throttle's function key command. The actions available are listed in the Function Key Action table. Use this step-by-step sequence to change what the decoder does when it receives a throttle function key command.

Changing The Action For a Throttle Function Key

Always start by thinking through what you want your M60X decoder does when you push a specific key on the throttle. For this example, here's what is wanted:

"On the throttle, I want the throttle's 9 key to turn on the A1 Light Output."

Notice the underline of the important items: which throttle key is to be used, and what the decoder action will be when that key is pushed. For this example, F9 is the throttle's 9 key. Now you are ready to set the M60X so that it performs the desired action when F9 is pressed.

Step 1: Find F9 in the Function Key Assignment table and note the CV number.

From the table, the Throttle Function 6 action is defined by the value in CV43.

Step 2: Find the desired decoder action in the Function Key Action table and note the value. This will be what is stored in CV43.

For this example, you want to toggle the A1 light output on and off. The CV value 3 is to be used.

Step 3: Program the decoder. First turn on your throttle. Verify the throttle frequency matches the M60X frequency and the red GP LED is on bright.

Step 4: SVC PROGRAM CV43 to a value of 3. The decoder will bump the motor indicating it heard and accepted the command. Push ESC to escape out of SVC PROGRAM and verify that the decoder's action is correct when the 9 key is pressed on the throttle. Since the original factory setting had F11 controlling the A1 output, you should program F11 to a value of 0 (no action).

Repeat this same sequence to setup or change the other decoder functions.

Function Key Action	CV#
F1 Function Key Action	CV35
F2 Function Key Action	CV36
F3 Function Key Action	CV37
F4 Function Key Action	CV38
F5 Function [Activate Cruise Control]	CV39
F6 Function Key Action	CV40
F7 Function Key Action	CV41
F8 Function Key Action	CV42
F9 Function Key [Toggle A1 Lite]	**CV43**
F10 Function Key Action	CV44
F11 Function Key Action	CV45
F12 Function Key Action	CV46

CV Value	Function Key Action
0	No Function
1	Activate Cruise Control
2	na
3	**Toggle A1 on/off**
4	Toggle A2 on/off
5	na
6	na
7	Dim Headlite rule 17
8	na
9	na
10-14	reserved
15	Activate Ditch Lites
99	Deactivate Cruise Control

Function key assignments are permanently stored in the decoder memory until changed or the decoder is reset.

Using The A1 and A2 Light Drivers

The M60X has 2 more independent LED drivers, called A1 and A2. Each driver can have a different lighting effect assigned to it. As with all the other M60X light drivers, a white LED is recommended which look best for all lighting effects. Be sure to include the limit resistor. Without the resistor , the LED will burn out and the driver may be damaged.

Assigning Throttle Function Keys To Control A1 and A2 LED Outputs - Recap

Controlling A1/A2 LEDs from the throttle is done by assigning a throttle function key using the table below.

The original factory setting for assigned function keys are F11 for A1 and F12 for A2.

To change the predefined function key, determine which throttle key will be used to control the specific A output and load the CV value into the CV number for the selected throttle function key.

F0 cannot be used. It is strictly for headlight control.

If the desired key has been previously assigned to a M60X function, a new assignment will automatically overwrite the old assignment.

If the previously defined key will not be used, program its CV to a value of 0 which is off.

Using A1 and A2 Drivers As Ditch Lights

The A1 and A2 light drivers have two modes of operation. The standard mode allows each output to operate independently. Each light driver can have separate special lighting effects. The second mode is where the two drivers are configured as a pair of ditch lights that can be triggered to flash by a function key.

Ditch Light Mode Set With CV96: To switch the A1/A2 drivers to ditch light operation, set a value of 1 into CV96. This automatically configures the two drivers to turn on when function 0 is pressed. A second throttle function key is then assigned to trigger the alternate flashing of the ditch lights.

Ditch Light Trigger: The original factory setting for triggering the ditch lights is throttle function key 4 (F4). You may assign any function (1 to 12) to trigger the ditch light flashing. Load the appropriate function key CV with a value of 15.

Ditch Light Operation: The ditch lights are both on when the headlights are turned on with F0. Now push the function key assigned to trigger the ditch light flashing. The flashing will continue for about 15 seconds and then stop with both lights turned on.

Reset Mode Back To Independent Drivers To disable the ditch light feature, set CV96 to a value of zero. With CV96 set to 0, the ditch light trigger will no longer affect the A1 and A2 outputs.