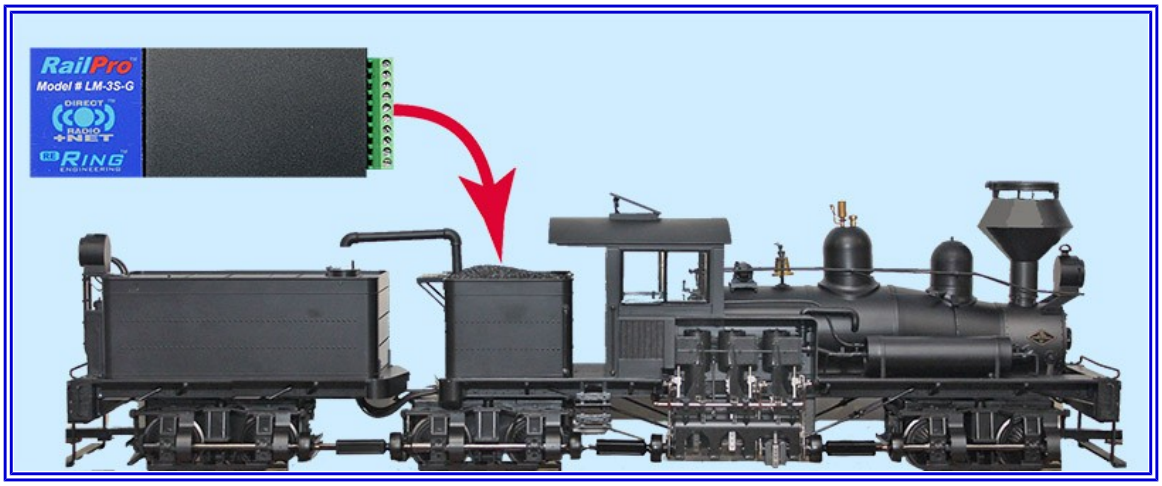
Installing a RailPro LM-3S-G Loco Module in a Bachmann Fn3 3-truck Shay Locomotive



by

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Table of Contents

INTRODUCTION

Read on to learn how I installed a RailPro (http://www.ringengineering.com/RailPro.htm) LM-3S-G locomotive module with sound in a Bachmann Fn3 scale 3-truck Shay locomotive. I hope this document helps you perform a smooth installation.

My background

I've been involved in model railroading for a long time, and modeled the Virginian Railway in HO scale (http://virginian.mdodd.com) from 1996 until 2008. I equipped all my locomotives with DCC sound decoders, and held regular operating sessions from 2000 until July, 2008, when the layout was dismantled and given to a friend who regularly attended op sessions.

My wife, Louise, and I moved to a new house in 2011, and I became too busy to begin a new Virginian layout. In 2017 I decided to forgo the Virginian, and model a proto-freelanced West Virginia logging railroad with geared locomotives in large scale. At first I planned to again use DCC to control the engines, but after hearing great things about RailPro, and learning more about the technology it uses, I chose that system instead.

This is my first-ever venture into large scale and Bachmann F scale products. As I understand it, Bachmann produced two or more versions of the 3-truck Shay and a Climax. I believe I have the latest versions of both engines, so the procedures I describe in this document for my Shay might not work for earlier versions.

Bachmann packed a lot of electronics into these engines! This is a blessing because it simplifies installing a loco module. But Bachmann did a poor job of documenting the internal electronics, so I had to do some detective work during my installation.

Fortunately, I have worked with electronics for many years, so figuring out the Shay electronics didn't take long.

Finding your way around this document

Throughout this document, "hyperlinks" to figures, tables, and other sections are shown in **bold green.** Click the mouse pointer on a link to go directly to that location. For example, clicking on **Let's go!** takes you to that section on page **4**. So does clicking the green **4**.

You also can click on a heading or page number in the table of contents to jump directly there.

Clickable Internet websites are shown in underlined blue.

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Usually you can add a "Back" (also known as "Previous View") button to your PDF reader's toolbar. If you're using *Adobe Reader,* right-click on the toolbar, click **Navigation**, then click **Previous View**. A left-arrow button should appear on the toolbar.

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Definitions

For brevity and clarity, I use certain terms in this document that have the meanings listed here.

- **Shay:** The Bachmann large scale (20.3:1)model of the 3-truck Shay steam locomotive, in particular, the later version that might differ from earlier versions.
- **Feature:** An object on the locomotive such as a light or smoke unit that can be turned on and off with an electronic signal.
- **RailPro:** The radio control system developed by Ring Engineering, inc. (http://www.ringengineering.com/RailPro.htm)
- **Loco module:** The RailPro Locomotive module suitable for this locomotive, model LM-3S-G.
- **9-pin connector:** The white connector with wires supplied with the loco module, and which plugs into a socket on one end of the loco module.
- **Trip-red:** My term for the condition where a PWR-56 power supply shuts off its output and displays a red light if it detects excessive output current.

Are you prepared?

I'll say at the outset that you should possess a few traits, abilities, and tools to successfully install a loco module in a Bachmann Fn3 Shay:

- **Patience.** Nothing is difficult, but the entire procedure has many details to pay attention to.
- **Common sense.** You need to understand at least the basics of each step, and say, "now wait a minute!" if something doesn't seem right. Then you need to figure out what's going on.
- **Basic soldering skill and tools.** Fortunately, all soldering is done on a simple "jumper board" outside the locomotive, so there is no chance of damaging the internal electronics. At minimum, you should be able to solder a wire to a printed circuit board (PCB). You'll also need basic soldering tools. See **Appendix D: About soldering** on page **26** for more information.
- **Basic modeling skill and tools.** If you've ever kitbashed a freight car or put together a structure kit, you probably have the skill needed to install a loco module. You need a well-lighted work space and basic tools like needle-nose pliers, wire cutters, and a small screwdriver. I found it useful to have a set of jeweler's screwdrivers, a set of drills, and a tap to thread a hole.

Acknowledgment

I bought my RailPro system from Don Sweet at RCS of New England (www.rcsofne.com). Don provided valuable information about how a loco module typically is installed in model locomotives, and described the purpose of some of its terminals.

I would have spent much longer figuring out these details without Don's help. ***Thank you, Don!***

Overview

The Shay can operate with straight DC or with a command control system like RailPro or digital command control (DCC). To accomplish this, internal electronic circuits control lights in response to low-power control signals. In other words, the control signals don't directly turn on lights or the smoke unit – they just command the internal electronics to do those things.

We don't need to wonder if the lights are incandescent lamps or light-emitting diodes (LEDs). We don't need to worry about incandescent lamp voltage or if we must install current-limiting resistors for LEDs. The internal electronics take care of everything – all we need to do is make a simple low-power electrical connection to turn on a light.

Let's go!

Installing a RailPro loco module in a Shay is straightforward. The loco module is installed inside the fuel bunker, where other electronic connections are made. A loudspeaker is installed in the water tank above the third truck. These are the steps:

1. Install a loudspeaker in the water tank.
2. Install the loco module in the fuel bunker, which involves:
   (a) Open the fuel bunker.
   (b) Identify the wires in the fuel bunker.
   (c) Identify the wires on the loco module.
   (d) Decide how to connect to the loco module.
   (e) Decide how to mount the loco module.
   (f) Connect the loco module to the fuel bunker PCB.
   (g) Mount the loco module.

Step 1: Install a loudspeaker in the water tank

Let's do the easiest task first – install a speaker inside the water tank.

- ☐ Unhook the drawbar connecting the water tank to the locomotive. Carefully disconnect the 8-pin connector carrying power, motor, light, and sound wires between the engine and the water tank.
- ☐ Use a #1 Phillips screwdriver to remove two small screws on the underside of the chassis near the rear end . Set the screws aside where they won't be lost. Lift up the rear of the shell and unhook the front from the chassis.

Storing parts

It's important not to lose parts removed from the locomotive and the loco module. I use the RailPro loco module box to store everything I remove.

Fig. 1 shows what you'll find. A small circuit board holds the 8-pin plug for the cable to the locomotive: two for track power, two for the motor, two for the rear headlight, and two for the speaker. The four track and motor wires duck through a hole in the center of the chassis. The headlight wires are already connected to that appliance. The speaker wires hang loose with insulating tape on their ends.

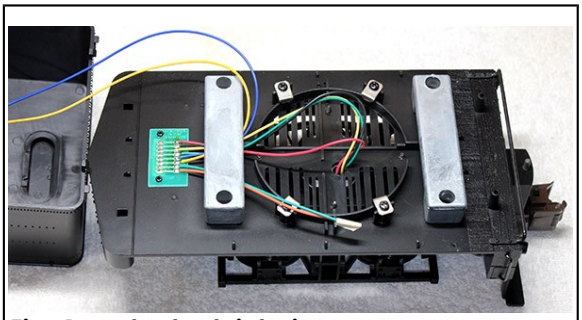

Fig. 1: water tank interior

Bachmann thoughtfully provided an opening in the chassis to let the sound out. Buy or scrounge a speaker that can be mounted above this hole.

I salvaged one from a pair of old computer speakers (the computer died, but not the speakers). I opened the case, removed the speaker (**Fig. 2**), then discarded the circuit board, switches, and wiring in it, I saved the second speaker of the pair for a future project.

Fig. 2: A suitable loudspeaker

According to the printing on the magnet, this particular speaker is rated for 3 watts of audio power – about right for an indoor layout like mine. You might need a higher-power speaker for outdoor running.

Before mounting the speaker on the chassis, we need to secure the four wires that run across the sound hole so they won't vibrate and rattle when the speaker produces sound.

Tape the four track and motor wires flat against the bottom of the sound hole, and secure them with dabs of viscous adhesive (yellow arrows in **Fig. 3**). I favor "Amazing" Goop* (http://eclecticproducts.com/products/amazing-goop.html), but any viscous adhesive will work as well.

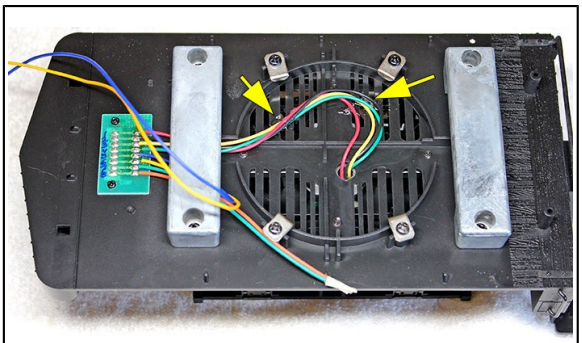

Fig. 3: Wires secured with Goop

** There are many varieties of Amazing Goop, but frankly, I haven't found much difference among them. I find "Plumber's Goop" but no other variety at Lowe's.*

When the glue is dry, remove the tape and work out a way to attach the speaker to the chassis. Be sure the two unconnected wires will reach the speaker's terminals.

As it happened, my speaker's diagonal hole spacing was very close to to the distance between two of the posts surrounding the sound hole. I removed the screws, discarded the small metal brackets, and screwed the speaker to the posts (**Fig. 4**).

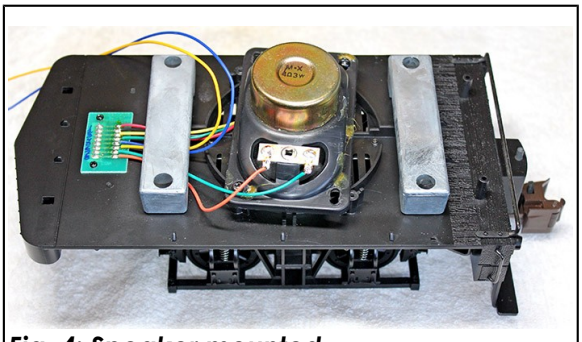

Fig. 4: Speaker mounted

Had the holes not matched, I would have glued the speaker to the ring around the sound hole with Goop.

Remove the insulating tape from the two unconnected wires and solder them to the speaker terminals. It doesn't matter which wire goes to which terminal.

Optional: Identify the wires on the 8-pin connector

We don't **need** to know the purpose of the other wires in this chassis, but for future reference, I used a fine-tip Sharpie permanent marker to number the pins on the circuit board at the front of the chassis. I also photographed the circuit board with the numbered pins, and added each pin's use to the photo (**Fig. 5**).

Fig. 5: 8-pin connector wires

Step 2: Reattach the tank shell.

With the speaker mounted and wired, we're ready to put the tank shell back on the chassis.

insert the two hooks on the front of the shell into the mating holes in front from the chassis, and lower the shell completely onto the chassis.

Screw the shell to the chassis using the two small screws you removed earlier.

Set the water tank aside while we work on the locomotive itself.

Step 3: Open the fuel bunker

Remove the coal or oil "cap" from the top of the fuel bunker. You'll find a weight screwed to the floor of the cavity under the cap. Remove this weight and set it aside.

Place the Shay on on a towel and turn it on one side. Use a #2 Phillips screwdriver to remove the screw under the running board near the rear of the engine (**Fig. 6**).

Turn the Shay on its opposite side and remove the second screw.

Gently lift the rear of the bunker shell and unhook the front from the floorboards. Set the shell aside and store the screws for when the job is complete.

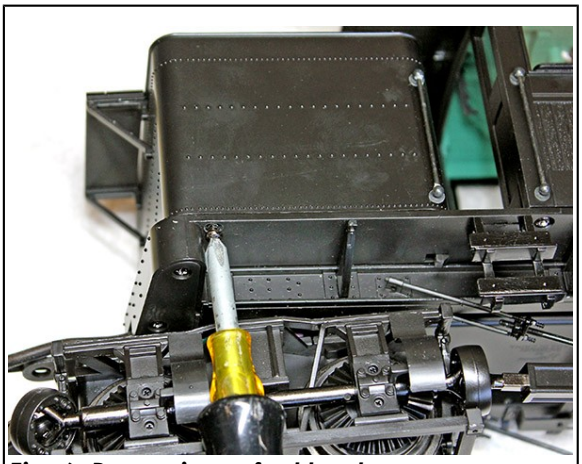
Fig. 6: Removing a fuel bunker screw

Handle PCB wires with care!

The wires soldered to the PCB can easily break off, so handle them with great care, especially when removing and replacing the bunker shell.

It's a good idea to photograph the wires soldered to the front and left (fireman's side) edge of the PCB so you can restore them if you later discover some broken off.

To resolder a wire, strip about 1/8" of insulation, then tin the wire by melting solder onto it. Melt a shall amount of solder onto the PCB pad where the wire broke, then lay the tinned wire end into the molten solder, remove the iron, and wait a few seconds for the solder to solidify.

It's better for the wire to exit the PCB horizontally, instead of vertically and then looping. You might want to unsolder/resolder any wire that appears ready to break, or reinforce the factory joint with more solder on the top side.

Step 4: Identify the wires in the fuel bunker

With the shell removed, you'll see a circuit board (PCB) with many wires connected to it; see **Fig. 7**. Fortunately, we're concerned only with the wires in the white connector in the lower-right corner, and the wires in the three 2-terminal green blocks next to that connector.

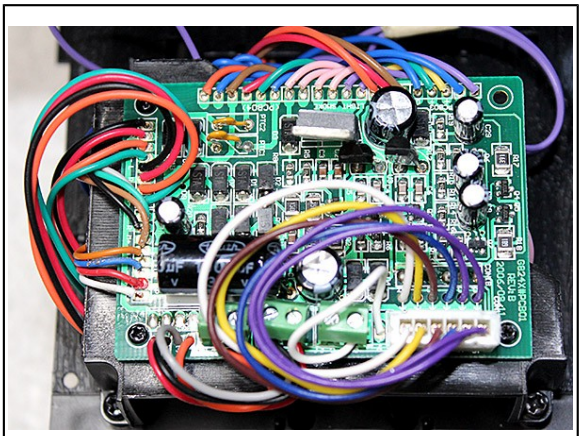

Fig. 7: PCB inside the fuel bunker

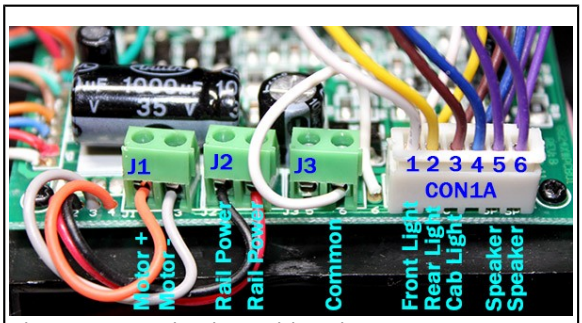

Fig. 8: PCB wire identification

Fig. 8 shows a closeup of these wires with their purpose added.

The three green terminal blocks are named J1, J2, and J3. The white connector is named CON1A, and the wires in the mating plug are soldered to CON1B pads on the PCB.

Step 5: Choose locomotive features to control with the loco module

As you can see in **Table 1**, the Shay lets you control the two headlights and the cab light, and send sound to the speaker in the water tank. The firebox flicker and smoke unit are on whenever track power is present on the PCB. Identify the features you want to control, and which outputs on the loco module will control them.

I chose to control all three lights. **Table 1 below** lists the lights and the loco module outputs I assigned to them. There is space for you to write your own assignments. Leave an assignment blank if you choose not to control that feature.

Feature	PCB CON1A Pin No.	My 9-pin Assignment	Your 9-pin Assignment
Front headlight	1	Output 1 (orange)	
Rear headlight	2	Output 2 (blue)	
Cab light	3	Output 3 (white)	
Speaker +	5	Speaker (red)	
Speaker -	6	Speaker (green)	
Smoke unit	Smoke unit pink wire ***See text***	Output 4 (yellow)	
Firebox flicker	Firebox brown wire ***See text***	Output 5 (gray)	
Ash pan flicker	Ash pan blue wire ***See text***	Output 5 (gray)	

Table 1: Engine feature pin assignments to loco module pins

Controlling the smoke unit

The two headlights and the cab light are powered by the PCB in the fuel bunker. All the loco module needs to do to turn them on is connect a low-level wire to a common terminal known as "ground" (Gnd) in the electronics trade. We aren't concerned about what voltage is applied to the lights, or if a current-limiting resistor is needed for an LED.

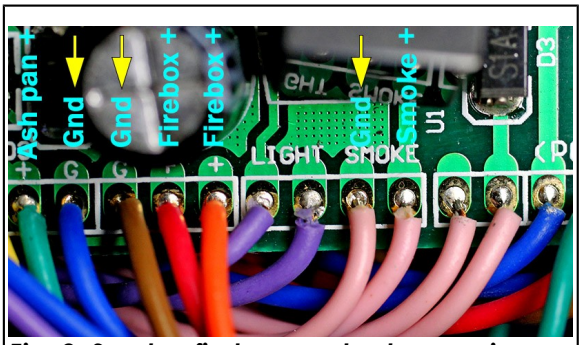

Fig. 9: Smoke, firebox, and ash pan wires

The smoke unit is different. It is powered from the PCB via two pink wires (see **Fig. 9**, **Smoke +** and **Gnd**) that carry the full operating current of about 150 milliamps (mA) when it's on.

There is no connector pin or terminal to switch the smoke unit on and off, so we must use one of the pink wires, and the loco module output must carry the 150 mA operating current. Fortunately, the LM-3S-G can handle this. Each output can carry up to 1,200 mA (not to exceed 1,200 mA on *all* outputs combined), so we can disconnect the Gnd wire (right yellow arrow in **Fig. 9**) and connect it to an loco module output to control the smoke unit.

We will return to this topic in the section about connecting the loco module to the PCB.

Controlling the firebox flicker

Three wires, red, orange, and brown, connect the firebox flicker unit to the PCB. The red and orange wires supply positive voltage (**+**) to the unit, and the brown wire is the common. I don't know why there are two **+** wires (but we don't need to know).

We will disconnect the brown Gnd wire (center yellow arrow in **Fig. 9**) and connect it to a loco module output to control the firebox unit. This wire carries only 2 mA of current, so we can treat it like a light-control wire.

We will return to this topic in the section about connecting the loco module to the PCB.

Controlling the ash pan flicker

The ash pan is the large box beneath the boiler and directly behind the three cylinders. A flickering red light similar to the firebox can be seen through a slot in the front of this box. Three wires, blue, green, and yellow, connect the ash pan flicker unit to the PCB. The green and yellow wires supply positive voltage (**+**) to the unit, and the brown wire is the common.

Two of these wires are visible in **Fig. 9**, but the yellow wire is out of view to the left. We will disconnect the blue Gnd wire (left yellow arrow in **Fig. 9**) and connect it to a loco module output to control the ash pan unit. This wire carries only 2 mA of current, so we can treat it like a light-control wire.

We will return to this topic in the section about connecting the loco module to the PCB.

Step 6: Decide how to connect the 9-pin connector to the white plug

As seen in **Fig. 8 above**, the white connector (CON1A) holds wires for the three lights and the loudspeaker. We must unplug this and connect its wires to the wires on the 9-pin connector's wires.

The question is, how shall we make these connections? There are three options:

1. Cut the wires and splice them to the 9-pin connector wires.
2. Plug one end of jumper wires made for Arduino microcontroller project boards into the white connector, and splice the other end to the 9-pin connector wires.
3. Solder the 9-pin connector wires to a "pin header" that plugs into the white connector.

These options are discussed below.

Option 1: Cut the wires and splice them

You might be tempted to simply cut the wires in the white connector and solder them to the 9-pin plug wires, insulating each with heat-shrinkable tubing. This will work fine, but limits your flexibility if the spliced wires aren't long enough, or you want to go back to the original configuration.

Option 2: Use Arduino jumper wires

The Arduino (https://www.arduino.cc/) is a microcontroller intended for easy hobbyist projects. It has sockets that allow external circuit boards to plug in using jumper wires with a pin or socket on each end.

These jumper wires come attached together in flat cables; you peel off as many wires as you need. **Fig. 10** shows such a cable with six wires being separated for the Shay project.

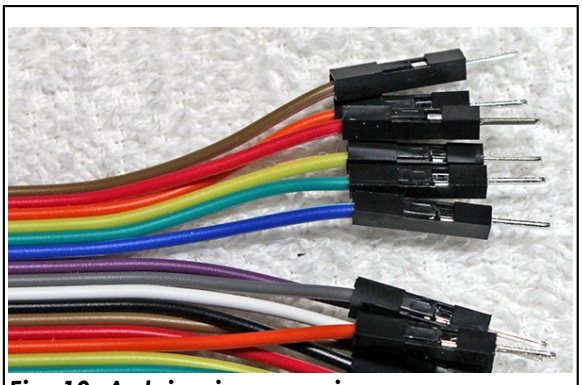

Fig. 10: Arduino jumper wires

With this option, we will plug the pins on one end into the white socket, cut off the pins on the other end, and splice the cut-off end to the 9-pin connector wires.

The benefit is, the wires on the white connector remain uncut, so you can plug it into its socket if ever you need to do so.

You can buy short jumper cables from Arduino suppliers like Sparkfun (https://www.sparkfun.com/products/12794) or on eBay (search for "Arduino jumper cable"). Be aware that some eBay sellers are in Asia, and shipping to the U.S. can take several weeks.

Option 3: Use a pin header

A pin header (**Fig. 11**) is a plastic strip that contains a row of square pins spaced 0.1" apart – the same spacing as the contacts in the PCB's white connector.

With this option, we will solder the 9-pin connector's wires to the short end of the header pins, and plug the long end of the pins into the white connector.

The benefit is, the wires on the white connector remain uncut, so you can plug it into its socket if ever you need to do so. Also, the header's plastic strip holds all six pins together, making a more secure connection than the individual pins on an Arduino jumper cable.

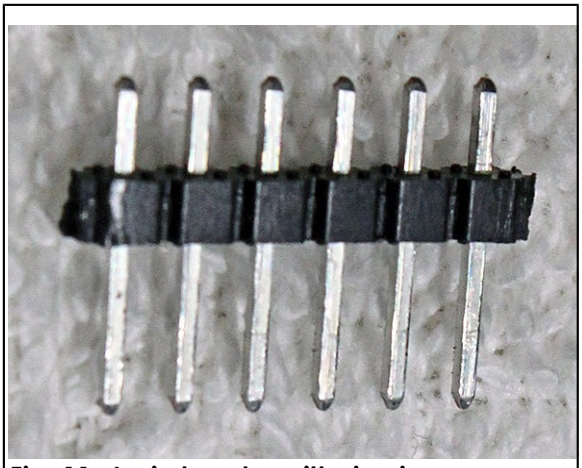

Fig. 11: A pin header with six pins

Pin headers are available in long strips with many pins from electronics suppliers like Digi-Key (item number WM6436-ND (https://www.digikey.com/products/en?keywords=WM6436-ND) and Mouser, and on eBay (search for "pin header"). cut the plastic strip to get the number of pins you need.

My choice: Option 3

I chose to solder the 9-pin connector wires to a pin header, and plug it into the white connector. Consequently, the section on connecting the loco module focuses on this option.

But wait – there's more!

Plugging into the white connector is convenient, but it contains wires for just three lights and the loudspeaker. We need to splice wires for:

- + voltage and common – loco module screw terminals
- Motor connections – loco module screw terminals
- Smoke unit – loco module 9-pin connector (optional)
- Firefox flicker – loco module 9-pin connector (optional)
- Ash pan flicker – loco module 9-pin connector (optional)

Clearly we can't avoid splicing some wires, so let's get started.

Step 7: Connect the 9-pin connector to the PCB white plug

Refer to **Table 1** and connect the 9-pin connector wires you chose for the three lights and loudspeaker to the PCB white connector. Depending on the option you selected, cut and splice the white connector's wires, use Arduino jumper wires, or use a 6-pin header. I used a 6-pin header; the upper half of **Fig. 15 below** shows the five wires soldered to the header (I added pin numbers to the photo to correspond with those in **Fig. 8**). The connections are

insulated with heat-shrinkable tubing – remember to slip the tubing onto the wires before soldering.

Step 8: Remove unused wires from the 9-pin connector

The LM-3S-G loco module user manual states, *"You can remove any unused wires from the nine pin connector by lifting the keeper on the connector and sliding the wire out of the connector."* Here is how I did this.

In **Table 1** I chose to use five of the six available outputs plus the two speaker connections, so I removed the Output 6 (purple) wire and the Input (black) wire.

The bit about "lifting the keeper" is more involved that you might think. The plug housing is made of slippery plastic, and there is little space to fit a tool under the keeper to lift it.

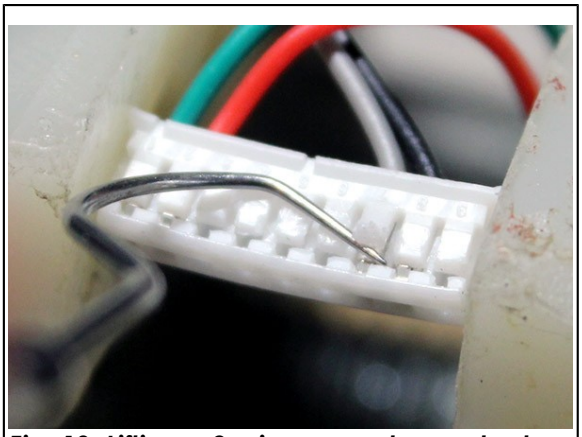

Fig. 12: Lifting a 9-pin connector contact keeper

After trying a small flat-blade screwdriver, I got better results with a dentist's pick. This fine-point tool was small enough to to slide under the keeper, and strong enough to lift it slightly to free the metal contact. Note in **Fig. 12** how the pick is lifting the keeper.

A very small jeweler's screwdriver ought to work as well. (Later (page **15**) you will need such a small screwdriver to secure wires to the loco module's screw terminals.)

While the keeper tab is lifted, gently pull the wire to remove the metal contact. Keep the wires in case you want to reinstall them in the plug. To reinstall, orient the contact so the tiny tab on its back faces the side of the plug with the keepers.

Push the contact into the square hold in the back of the plug until you hear a faint click, indicating the keeper has locked behind the tab. You can use a small screwdriver to push the contact all the way into the hole.

Step 9: Connect the 9-pin connector to the smoke, firebox, and ash pan wires

This step is optional. As factory-connected, the smoke unit will be on whenever power is applied to the PCB and the smokebox switch is set to "on." The firebox and ash pan units likewise will flicker whenever power is applied to the PCB (there is no switch for these).

If you choose to control these features with the loco module, you will unsolder wires connected to the Shay's electronic circuits and splice them to 9-pin connector wires. First read the information about soldering on page **26**.

Next, refer to **Table 1** and **Fig. 9** to understand which wires to unsolder from the PCB. Then perform the following steps.

- ☐ Unsolder the smoke unit Gnd wire. This is the leftmost pink wire in the group of four, with with the right yellow arrow in **Fig. 9**. The unsoldered wire is circled in **Fig. 13**, to the right.

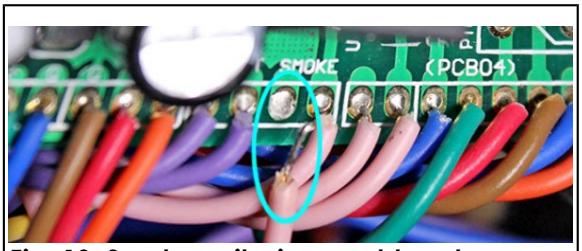

Fig. 13: Smoke unit wire unsoldered

- ☐ Unsolder the firebox and ash pan Gnd wires. These are the brown and blue wires with the center and left yellow arrows in **Fig. 9**. The two unsoldered wires are circled in **Fig. 14**, to the right.

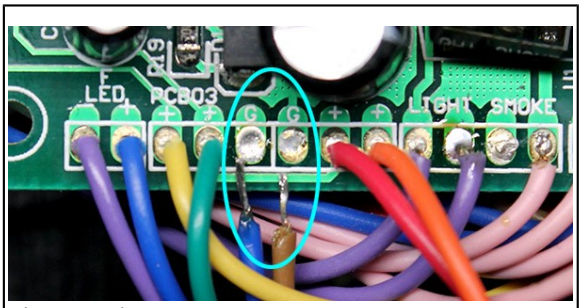

Fig. 14: Firebox (brown) and ash pan (blue) wires unsoldered

- ☐ Splice the three unsoldered wires to the corresponding wires from the loco module's 9-pin connector, as you chose in **Table 1**. Be sure to insulate the splices with heat-shrinkable tubing.

  The lower half of **Fig. 15** shows my splices for the smoke unit, firebox, and ash pan. Notice that I use Output 5 (gray wire) on the 9-pin connector to control **both** "flicker" units together. It makes little sense to have one flickering without the other (if anyone ever sees them at all!).

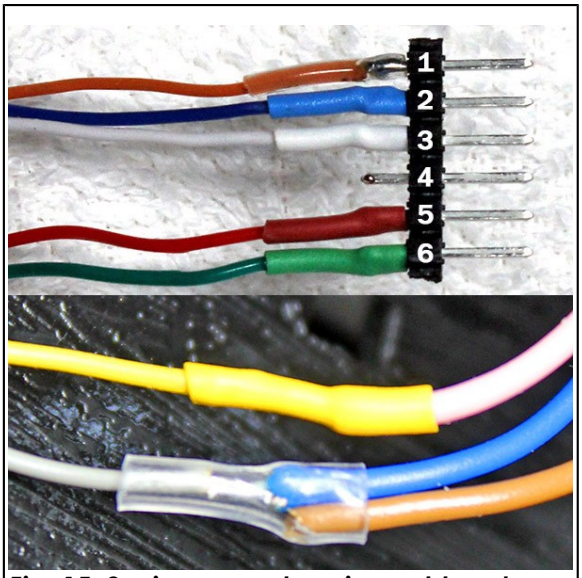

Fig. 15: 9-pin connector wires soldered

Step 10: Understanding the power and motor connections

The factory wiring brings track power to the PCB, which then delivers it to the motors, and also uses it for lights and other features. Fortunately for us, Bachmann made it easy to separate these connections.

Fig. 8 is duplicated here for ready reference to identify the PCB power and motor connections. **Table 2 below** explains how these connections are used, and the modifications we will perform to use them with the loco module.

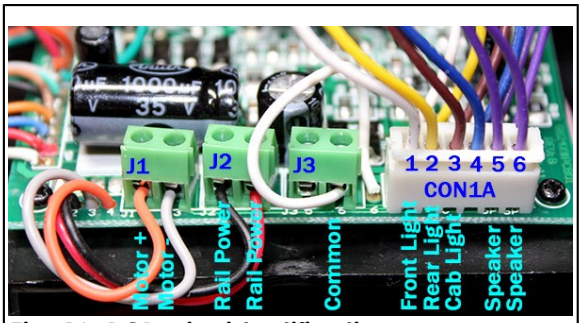

Fig. 16: PCB wire identification

Use	Terminal Block	Wire Color	Original Use	Our Modification
Rail power	N/A	Black	The red and black wires supply power **from** the track. They are factory-connected to the J2 terminal block to supply power **to** the PCB, and out again via J1 to run the motors.	We will disconnect the red and black wires from J2, and connect them to the **Track** screw terminals on the loco module to supply power to it.
Rail power	N/A	Red		
Power **to** PCB	J2, left screw	N/A		We will add wires from the **Voltage +** and **Common** screw terminals on the loco module to J2 to power the PCB.
Power **to** PCB	J2, right screw	N/A		
Motor + **from** PCB	J1, left screw	N/A	The J1 screw terminals supply power **from** the PCB **to** the motors. The orange and gray motor wires are factory-connected to these terminals.	We will disconnect the orange and gray motor wires from J1, and connect them to the loco module, which powers the motors.
Motor - **from** PCB	J1, right screw	N/A		
Motor + **to** motor (see **Error: Reference source not found**)	N/A	Orange		We will connect the orange and gray motor wires to the **Motor 1 +** and **Motor 1 -** screw terminals on the loco module to power the motors.
Motor - **to** motor (see **Error: Reference source not found**)	N/A	Gray		
Common	J3	White	The common point for PCB electronics.	We will leave the white wire connected from the PCB solder pad to J3, and add a wire from J3 to the **Common** screw terminal on the loco module to provide a return path for the output signals on the loco module's 9-pin connector.

Table 2: Power and motor connections and modifications

Step 11: Connect power and motor wires to the loco module

The final wiring step is to connect the Shay's power and motor wires to the loco module screw terminals. **Table 3** lists the wires we'll connect, and where they connect.

Important! Before proceeding, please read Error: Reference source not foundError: Reference source not found on page Error: Reference source not found. You might decide to remove the large black capacitor seen behind the green terminal blocks in **Fig. 16**. If so, do it now, before connecting the power and motor wires to the loco module, and before replacing the fuel bunker shell.

About motor polarity

The orange **Motor +** and gray **Motor -** designations are correct only if the Direction switch behind the Shay's smokebox door is set to **NMRA**. If it is set to **Large Scale**, the polarity is reversed – the black wire is **Motor +** and the orange wire is **Motor -**.

This doesn't make any difference with RailPro because you can reverse the locomotive direction in the hand control setup.

About the loco module's terminal block screws

In the steps below, we'll connect wires to the loco module's screw terminal block. The screws in the terminal block are *tiny*. My smallest flat-blade screwdriver wouldn't fit into the hole. Time to break out the set of jeweler's screwdrivers! Even then, I had to use the third-smallest blade to reach the screws.

We don't use the 5-volt connection

Page 7 in the LM-3S-G owner manual shows a wire from the +5 volts screw terminal to locomotive lights, and current-limiting resistors between the lights and the 9-pin connector. It also issues warnings about damaging LEDs with incorrect current-limiting resistors.

We do not need +5 volts or resistors because the Shay's internal electronics take care of that for us. *The loco module needs only to connect a control pin to the Gnd pin turn on a feature.*

PCB Wire Color or Terminal	Loco Module Screw Terminal	Use
Black	Track	Rail power **to** loco module
Red	Track	Rail power **to** loco module
J2 (either terminal)	Voltage +	Loco module power **to** PCB
J2 (either terminal)	Common	Loco module Gnd **to** PCB
J3, terminal with white wire	Common	Return for loco module output signals
Orange	M1+ (see **About motor polarity, above**)	Loco module motor power **to** motors
Gray	M1- (see **About motor polarity, above**)	Loco module motor power **to** motors

Table 3: Wires between the PCB and the loco module

Begin by disconnecting the orange, gray, black, and red wires from J1 and J2 on the PCB. Use a small flat-blade screwdriver to loosen each terminal. **Fig. 17** shows these four wires disconnected. Note the factory-installed white wire from the PCB to J3. We will add a wire to that J3 terminal.

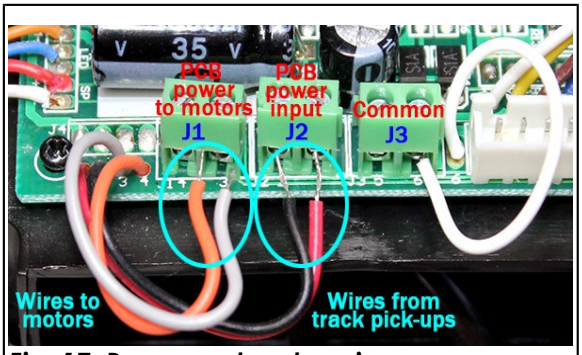

Fig. 17: Power and motor wires disconnected

About power and motor wires

In the next steps we'll add power and motor wires between the loco module and the PCB. I recommend using *stranded* wire because it's more flexible than solid wire, and is easier to route in the confined space of the fuel bunker.

I was fortunate to have a spool of decades-old multi-conductor audio cable with 22-gauge stranded wires (**Fig. 18**, top), but the stranded wires in CAT5 Ethernet cable (**Fig. 18**, bottom) will work as well.

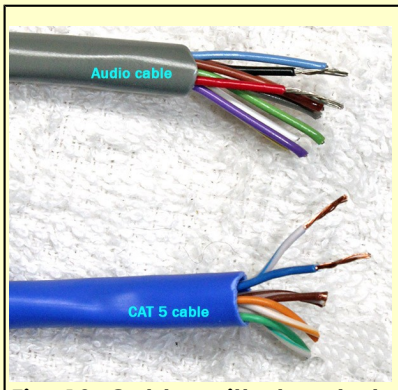

Fig. 18: Cables with stranded wires

It's a good idea to use the same or similar insulation color when splicing wires from the PCB to reach the loco module. This helps ensure you connect the correct wire to a terminal.

Finally, cut these wires long enough to ready the loco module where you plan to install it (see **Step 13** on page **18**). I cut mine 6" long to allow the bunker shell to be easily removed.

Use **Table 3** and **Fig. 17** for reference, and perform the following steps:

- ☐ Splice a wire to the disconnected **red** track power wire).
  - ☐ Connect this wire to one of the loco module terminal block **TRK** terminals. It doesn't matter which one.
- ☐ Splice a wire to the disconnected **black** track power wire).
  - ☐ Connect this wire to the other of the loco module terminal block **TRK** terminals. These two wires supply power to the loco module.
- ☐ Splice a wire to the disconnected **orange** Motor + wire).
  - ☐ Connect this wire to the loco module terminal block **M1+** terminal.
- ☐ Splice a wire to the disconnected **gray** Motor - wire).

- ☐ Connect this wire to the loco module terminal block **M1-** terminal. These two wires supply power from the loco module to the motors.

- ☐ Connect a wire from the loco module terminal block **+V** terminal to the left screw terminal on PCB terminal block **J2**. Which terminal doesn't matter electrically, but next we'll put two wires into the vacant terminal, and this is easier if that is the right terminal.
- ☐ Add an extra wire to the screw terminal on PCB terminal block **J3** that already has a white wire from the PCB in it; see **Fig. 17**. insert the other end of this wire into the vacant terminal on **J2**, but don't tighten the screw yet.
- ☐ Connect a wire from the loco module terminal block **Com** terminal to the **J2** terminal that has the wire from **J3** added in the previous step. Tighten the screw to secure these two wires
- ☐ This wire provides the return path for the output signals on the loco module's 9-pin connector. **J2** now should have two wires in one terminal, one connected to **J3**, and the other connected to the loco module **Com** terminal.

This photo shows the the power and motor wires spliced and connected after performing the steps above. I routed these wires under the PCB mounting bracket, and behind one leg to reach the loco module without sharply bending the wires in the PCB terminal blocks.

Note: we will disconnect the wires from the loco module terminal block and unplug the 9-pin connector after an initial test.

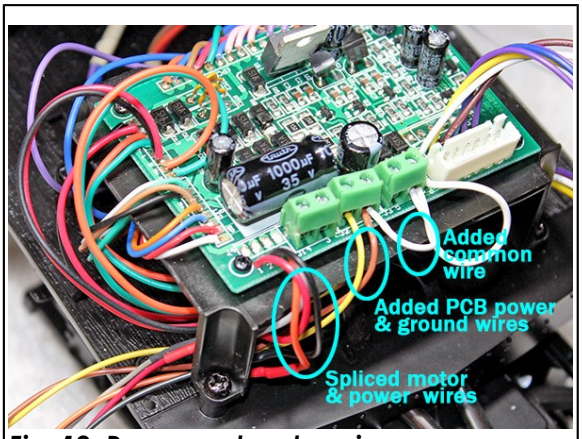

Fig. 19: Power and motor wires

Step 12: Test the loco module

Wiring the loco module to the PCB is complete. Now we test it with a RailPro power supply and hand controller to verify that it controls the Shay properly. Do the following:

- ☐ Connect the wires from the loco module 9-pin connector to the PCB white connector using the method you chose in **Step 6**. Be sure they are connected to the correct pins.
- ☐ Temporarily set the loco module on top of the PCB for this first test (**Fig. 20**).
- ☐ Connect your RailPro PWR-56 power supply to the track as directed in step 6 on page 4 of the LM 3S-G loco module user manual: *"Connect the power source...."*

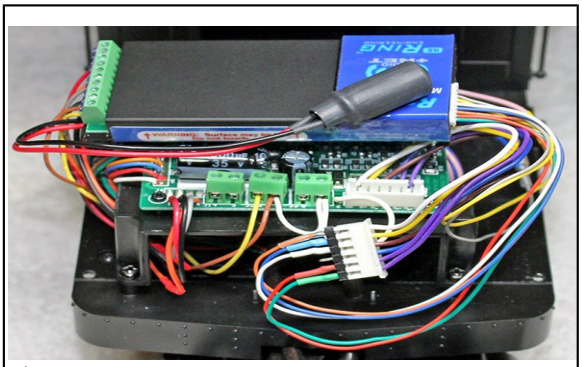
Fig. 20: Loco module ready to test

- ☐ Skip to step 8, *"Power-up the module,"* then continue with steps 9 – 12. Be sure to perform the "Motor Full Current" calibration; the engine will not run until this is done.
- ☐ Check the locomotive features listed in **Table 1** that you connected with wires from the 9-pin connector.

- ☐ Also check one or more sounds to confirm the built-in speaker is connected to the loco module.
- ☐ If everything operates as expected, ***congratulations!*** You have successfully installed a loco module in a Bachmann 3-truck Shay. All that remains is to make the installation permanent; continue with **xxx**.
- ☐ If something doesn't work, check the following:
  - ◊ Nothing works – Check the track power wires on the loco module TRK terminals, and on J1 pins 1&2 and 11&12.
  - ◊ Motor doesn't run – Did you perform the "Motor Full Current" calibration?
  - ◊ Motor still doesn't run – Check the motor wires on the loco module **M+** and **M1-** terminals, and J1 pins 3 and 10 on he jumper board.
  - ◊ One or more locomotive features don't work:
    - ▫ Check that the wires from the 9-pin connector to the PCB white connector are connected to the correct pins, as listed in **Table 1**.
    - ▫ Use the hand controller to check which hand controller buttons control which outputs. Reassign these if necessary.

Step 13: Final installation

I chose to install the loco module in the cavity on top of the fuel bunker beneath the coal load "cap." If you use the *fuel oil* cap instead, check carefully for sufficient clearance before performing the following steps.

Remove the studs under the fuel bunker cap

We must remove four studs on the underside of the fuel bunker cap interfere with the loco module beneath it. angled rail cutters to clip the studs at their base. See **Fig. 21**.

There is nearly enough clearance above the loco module with the studs removed.

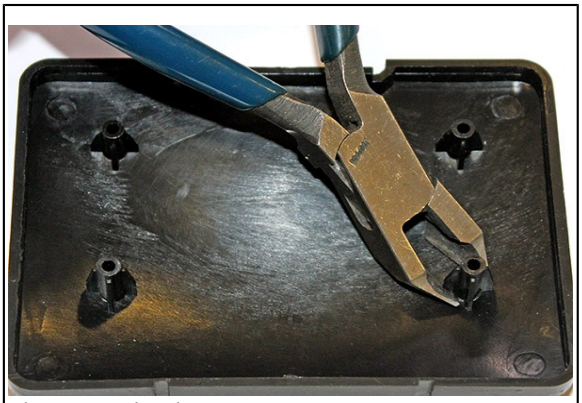

Fig. 21: Clipping the coal cap studs

But not quite. The flat bottom of the cavity under the cap has a short stud used to hold a weight, plus two tiny pins. These protrusions elevate the loco module, and should be removed to provide maximum clearance between the top of the loco module (which can become hot) and the underside of the plastic cap, which might soften or melt from too much heat.

Clip the stud and the two pins, as shown in **Fig. 22**.

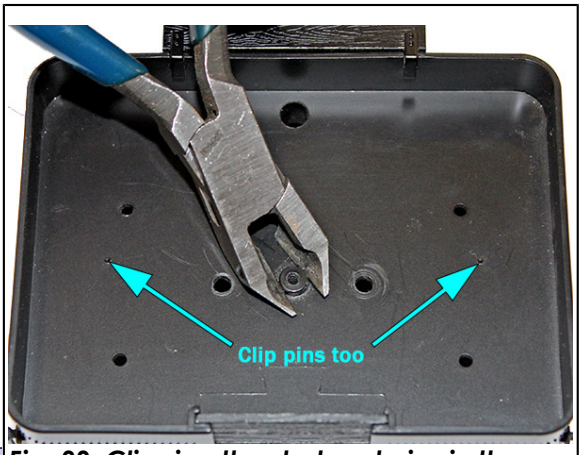

Fig. 22: Clipping the stud and pins in the bunker cavity

Drill holes for the loco module wires

The loco module will be installed on the flat bottom of the cavity toward the rear, but clear of the hole for the water spout (center-top hole in **Fig. 23**).

Drill two holes in the flat bottom near the rear corners of the cavity (**Fig. 23**). I started with a ¼" bit, then used a taper reamer to enlarge the hole to nearly ½". Drill slowly to avoid cracking the plastic. Using a reamer to achieve the final size is safer than attempting to drill with a large bit.

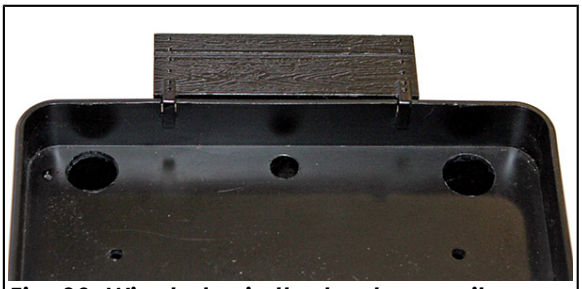

Fig. 23: Wire holes in the bunker cavity

Wait!

Please read **Appendix B** before proceeding.
You might want to remove a large capacitor from the electronics board inside the bunker before connecting the loco module and attaching the shell.

Disconnect the loco module wires

First list the color of the wires connected to the loco module terminal block, then loosen the screws and remove the wires. Carefully unplug the 9-pin connector from the loco module. *Don't pull on the wires.* Instead, use a small flat-blade screwdriver to alternately pry up the ends of the 9-pin connector.

Feed the 9-pin connector wires into the bunker cavity

Gently bend the wires on the 9-pin connector so the connector body is roughly parallel to the wires. Poke the connector and wires through the hole on the hole you drilled on the engineer's side of the bunker cavity (left hole in **Fig. 23**).

When through, straighten the wires so the connector is again perpendicular to them, and plug the 9-pin connector into its mating socket on the loco module. Be sure to push the connector firmly all the way into the socket. *Push on the connector body, not on the wires.*

Feed the power and motor wires into the bunker cavity

Tape the ends of the six power and motor wires together, then feed the bundle through the hole you drilled on the fireman's side of the bunker cavity (right hole in **Fig. 23**). Reattach the wires to their respective terminals on the loco module terminal block, as you did in the steps on page **16**.

Attach the bunker shell to the locomotive chassis

Refer again to **Step 3**, where you removed the fuel bunker shell. Now reverse the steps to re-attach it.

First ensure that the wires from the PCB to the loco module are routed directly upward. They cannot run downward because they'll be trapped between the PCB and the shell, preventing the shell from seating correctly on the chassis.

With the wires clear, lower the shell over the PCB (*remember to install the little coal pile in the slots at the center-bottom of the front side*). Tilt the rear upward so the two hooks on the

bottom of the front wall engage the mating holes in the locomotive deck. Be sure no wires are trapped between the shell and the deck on any of the four sides.

With the shell still tilted, push it forward until the hooks snap completely into their mating deck holes. This can be difficult, and you might need to press on each hook with a small screwdriver while pushing the shell forward to get the hooks mated.

Now replace the two screws holding the shell to the deck.

Mount the loco module to the bunker cavity floor

With the fuel bunker intact, we can mount the loco module.

First lay the loco module on the cavity floor in its intended location. Leave space at each end for the wires, and bend the wires so the module fits. Be sure the module is clear of the hole in the deck for the water spout (center-top hole in **Fig. 23**).

Attach the loco module to the cavity floor. I used double-sided foam tape, but a viscous adhesive like "Amazing" Goop will work fine.

Push any excess wire back through the deck holes into the PCB area.

Loop the red and black wires attached to the capacitor, and lay the capacitor on the cavity floor. Glue it if you're concerned about it rattling around during locomotive operation.

As seen in **Fig. 24**, I looped the wires under a corner of the loco module.

Before replacing the coal load cap on the fuel bunker, I cut ¼" off one side of the weight, and glued it to the cavity floor, leaving space between it and the loco module for ventilation, and the front side to allow the coal cap to fit.

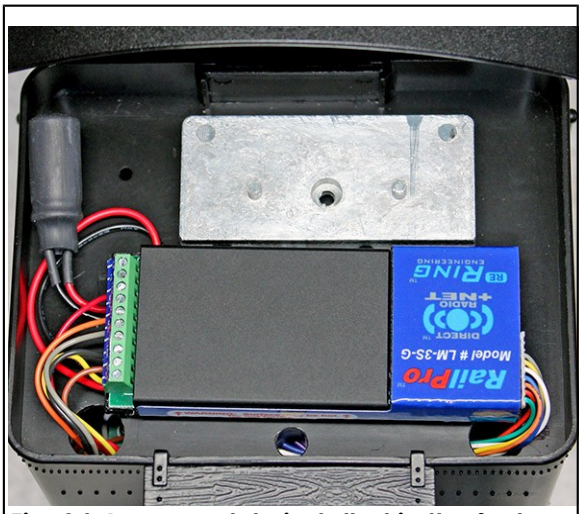

Fig. 24: Loco module installed in the fuel bunker cavity

Done!

Set the Shay on the track along with the water tank behind it. Hook the drawbar to the water tank, and plug the the 8-pin connector into the mating socket on the water tank.

- Check that the locomotive responds to the hand controller, and runs normally. Remember to first perform the "Motor Full Current" calibration in the loco module user manual.
- Verify that the motor in the water tank truck runs in concert with the motors in the main trucks.
- Command a sound and verify that it plays through the speaker in the water tank.
- Turn on the rear headlight, and confirm that it illuminates.

If anything doesn't work, refer back to **Step 1** on page **4**, and troubleshoot your wiring.

That's it – your Shay can now be controlled with a RailPro hand controller via a radio link.

Congratulations on a job well done! Enjoy your large scale model railroad.

APPENDIX A: COMMENTS ABOUT THE RAILPRO PWR-56 POWER SUPPLY

I learned a few things about the PWR-56 power supply while installing and testing two LM-3S-G loco modules.

A notice on the PWR-56 Web page (http://www.ringengineering.com/PWR-56.htm) states:

> ***IMPORTANT NOTE for G Scale Users***
>
> *The PWR-56 was primarily designed for HO scale locomotives but can be used to power G scale locos that use our LM-3S-G Module. The PWR-56 has enough power for 1-2 G scale locomotives with LM-3S-G modules installed. The PWR-56 has about 20% less voltage than a typical G scale power supply so your trains top speed will likely be about 20% slower.*

The PWR-56 user manual says it produces 14.5 volts at up to 4 amps current. Surely 4 amps is enough current for more than two G scale engines running at realistic speeds with moderate-length trains. Is maximum running current really the limiting factor? I don't think so.

What is the limiting factor?

If the 4-amp maximum running current doesn't prevent running three G scale engines at once, what *does*? ***Answer: A power-up current surge that trips the PWR-56.***

My tests revealed that the PWR-56 trips-red (overload, red light) immediately at power-up if detects a current surge – even a brief one – that exceeds its maximum current rating.

- Large capacitors on a locomotive's internal electronics boards can cause a surge.
- So too, apparently, can the LM-3S-G loco module. In my tests, a PWR-56 that powers-up normally with both my engines on the track trips-red at power-up with a third LM-3G-S connected to the rails.

In my opinion, the combined power surge of three LM-3S-G loco modules – not the maximum running current – is the reason for the "1-2 G scale locomotives" website notice.

A solution

I discovered that introducing ***a one-second delay between powering-up the PWR-56 and connecting its output to the track eliminates the trip-red*** with three LM-3S-G loco modules connected.

Appendix C describes a circuit I built to do this automatically. With this circuit wired between the PWR-56 and the track, the PWR-56 powers-up normally with a third LM-3S-G loco module connected to the track.

I also tested the time-delay with the internal capacitors still in my two engines, and the PWR-56 powered-up normally with both engines on the track. I did not test it with the capacitors *and* a third LM-3S-G loco module, but I expect the PWR-56 would power-up normally.

Bottom line

If you remove your engines' large capacitors, the PWR-56 will power-up correctly with ***two*** G scale engines on the track with LM-3S-G loco modules installed. But if you want to run three or more engines, you should install a track power delay circuit.

Appendix B shows how to remove the capacitor, and **Appendix C** describes the delay circuit.

Appendix B: Replacing the large capacitor inside the engine

Overview

The Bachmann Shay contains at least two electronic printed circuit boards (PCBs) that interconnect track power pickups, motors, lights, and other features. Ring Engineering recommends removing the internal electronics, and connecting everything to the locomotive module.

I studied the Bachmann wiring diagrams and identified the PCBs in the locomotive. It became clear that "removing the internal electronics" is not a simple process, but involves major surgery in the engine. So I decided to keep the internal electronics, wire the loco module to trigger them, and let the internal electronics actuate the feature lights.

I have two G scale engines – this 3-truck Shay and a Climax. With both on the track, the large capacitors on their internal PCBs produced a large current surge on power-up, causing the PWR-56 to trip-red. Removing a large capacitor in each solved the problem.

Follow the steps below to remove the large capacitor in the Shay, and read this corresponding Appendix B in the Climax document for details about that engine.

Please read "**Bottom line**" **above** before you decide to remove the capacitor.

Step B-1: Remove the capacitor

The fuel bunker shell must be removed to make the PCB accessible. Thus, it is easiest so remove the capacitor before **Step 13: Final installation**, where you connect the power and motor wires to the loco module and reattach the shell.

Locate a large capacitor near one corner of the PCB, next to two green screw terminal blocks. On my Shay, the capacitor was a black cylinder with a white stripe along one side. It was marked '1000µF 35V." **Fig. 25** shows the capacitor circled in red.

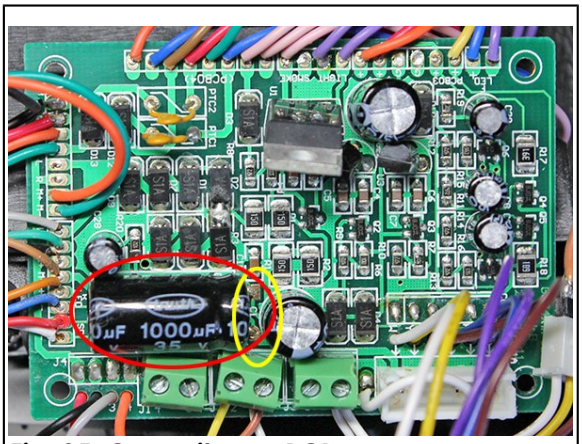

Fig. 25: Capacitor on PCB

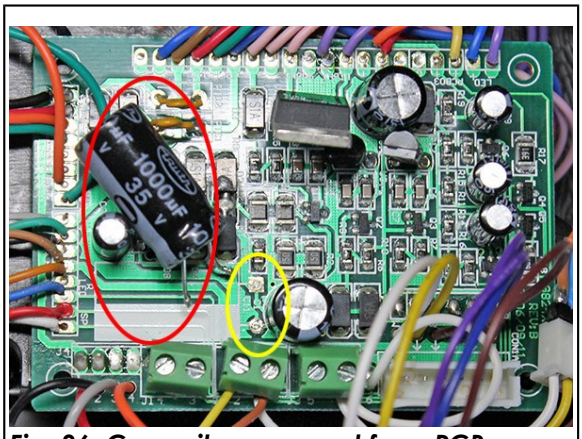

Fig. 26: Capacitor removed from PCB

There are two ways to remove the capacitor: unsolder it or cut its leads. The two wire leads are circled in yellow in **Fig. 25**. I chose to unsolder it. First I used a soldering iron to melt the solder on one pad, and pulled the wire loose with needle-nose pliers. Then I unsoldered the other lead the same way. **Fig. 26** shows the removed capacitor and the empty pads on the PCB.

It might be easier for you to cut the capacitor's leads instead of unsoldering them. If so, cut them close to the PCB so they can't touch each other or any other PCB points, and cause a short-circuit.

Set the capacitor aside – don't leave it lying on the PCB as seen in **Fig. 26**! It's a good idea to not discard the capacitor, in the unlikely event you'll need to replace it sometime.

Step B-2: Final test

Place the Shay on the track and power-up your RailPro system. Verify that the PWR-56 power supply does not trip. Verify that the engine runs, and that all features you connected operate as expected.

If you have two engines, remove the capacitor from both, and confirm that the PWR-56 powers-up without tripping with both engines on the track.

APPENDIX C: A TRACK POWER DELAY CIRCUIT

The PWR-56 checks for an overload immediately after powering-up. If locomotives on the track cause a large current surge, the PWR-56 trips-red. The same thing happens if there are three LM-3S-G loco modules connected to the PWR-56.

The PWR-56 doesn't trip-red if its output current is limited briefly immediately after power-up. I built a simple time-delay circuit that connects a 4.7-ohm resistor in series with one track wire to limit the current, then bypasses that resistor to supply full track power. See the diagram below.

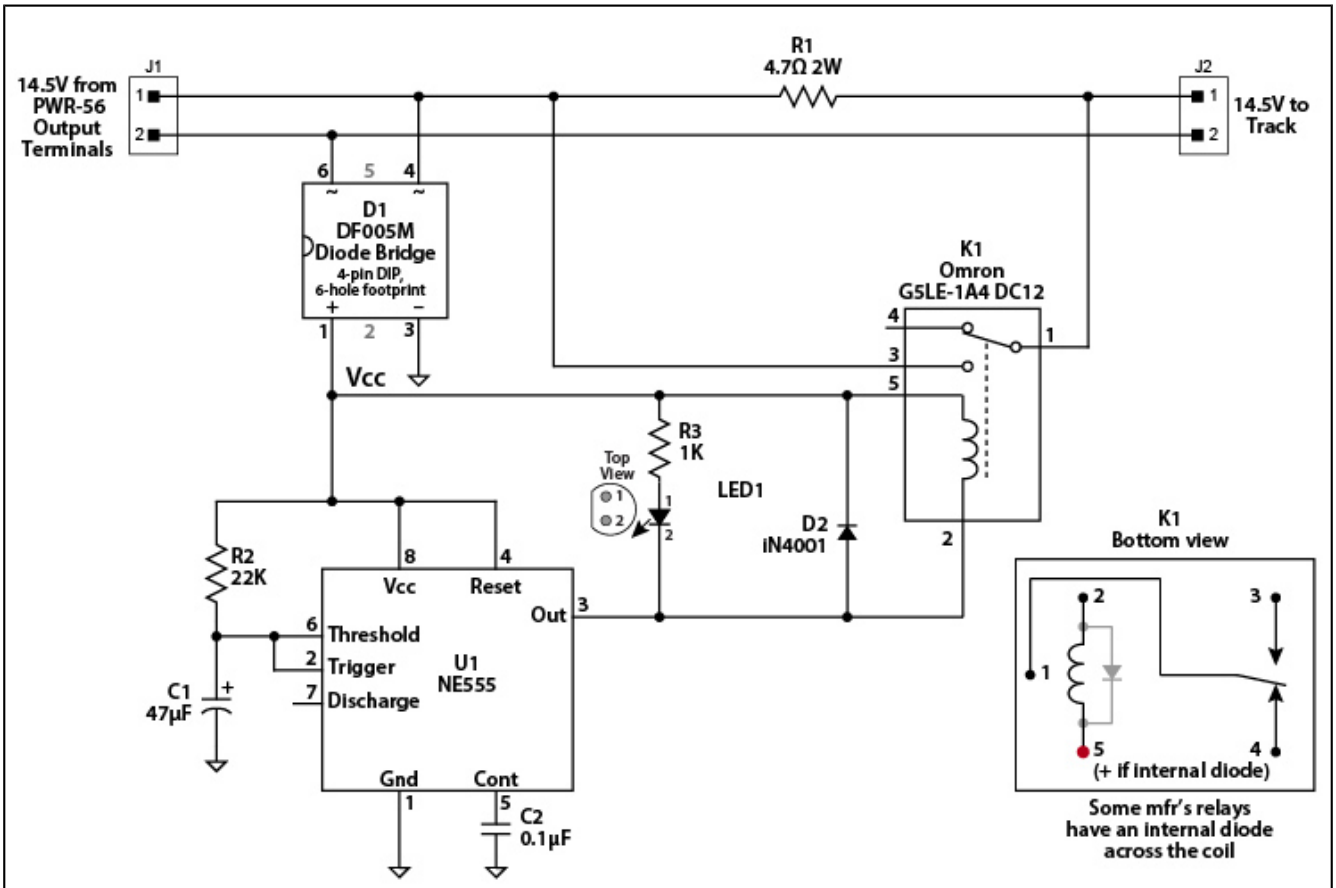

Fig. 27: Track power delay schematic diagram

Circuit description

Beginning at the top of the diagram, the PWR-56 output terminals connect to J1, and the track wires connect to J2. Resistor R1, 4.7 ohms, limits the track current to about 3 amps **(Ohm's Law: 14.5 volts / 4.7 ohms = 3.085 amps)** – well below the PWR-56's 4-amp maximum. The time delay allows everything connected to the track to charge-up and stabilize at the lower current, so the PWR-56 doesn't trip-red.

The remainder of the diagram includes:

- D1 is a diode bridge that accepts PWR-56 output voltage of either polarity, and supplies the correct polarity to this circuit.

- K1 is a relay with 10-amp contacts that shunts R1 after one second, and carries track current during normal operation.
- U1 is an NE555 timer chip wired to hold its output (pin 3) high for the length of time determined by R2 and C1, approximately one second. At the end of that delay, U1 pulls pin 3 low, which energizes K1 to shunt R1 and allow full current to pass to the track.
- D2 is a diode that protects U1's output pin 3 by suppressing the opposite-polarity voltage spike produced by the coil in K1 when it is de-energized. Some relays have an internal diode, but D2 is included to protect U1 with relays from *any* manufacturer.
- LED1 and R3 provide a positive green indication when K1 is energized and shunting R1 to provide full power to the track.

Circuit board

Fig. 28 shows the track power delay breadboard I hand-wired. I will provide circuit boards and parts kits if there is sufficient demand from the large scale community. Send an email to mike@mdodd.com if you are interested.

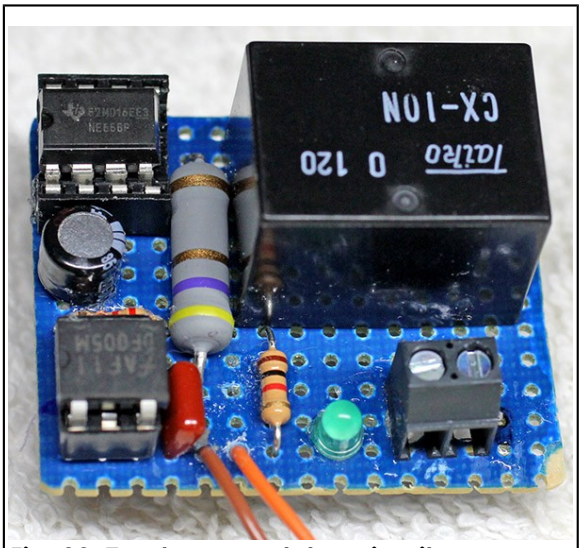

Fig. 28: Track power delay circuit breadboard

Appendix D: About soldering

Soldering tools

When connecting wires between the loco module and the PCB, you will need to solder them together or to a pin header. You will need need to *unsolder* several wires from the Shay's PCB if you choose to control the smoke unit or the firebox and ash pan flicker units. These tasks are easy with right tools.

- Use a small "pencil" soldering iron rated for about 30 watts. This one from All Electronics https://www.allelectronics.com/item/ir-258/16-30w-vari-temp-soldering-iron/1.html is suitable for this project. Its tip is grounded through the power cord, which helps prevent damage to sensitive electronics devices from static electronics.
- Use solder that has a core of rosin flux that cleans the metal as the solder melts. This solder is suitable: https://www.allelectronics.com/item/ts-110/60/40-solder/1.html
- You don't need separate flux if you use rosin-core solder. If you *do* decide to use separate flux, use ***only*** rosin flux. ***Never*** use plumber's acid flux, because it will corrode wires and the copper on the circuit board.

Soldering tips

- Before touching the soldering iron to a point connected to electronic devices (e.g., a wire or component on the PCB), touch a metal object like a lamp to discharge any static electricity your body has accumulated.
- Hold the iron tip on a PCB pad as briefly as possible. When soldering, this means just until the solder melts and flows across the pad and onto the wire in the hole. When unsoldering, this means only until the solder melts and you can pull the wire loose.
- Remember, you're working on a PCB inside a plastic model – it takes only a brief touch from a hot soldering iron to melt a horrible blemish into it! Be mindful of the model as you move the soldering iron to and from the PCB.

Unsoldering aides

When unsoldering wires, it's a good idea to clear the hole of excess solder if you will later solder a wire in that hole; there is no need to clear a hole if you won't be soldering a wire in it. Two products can help clear holes of solder:

- "Desoldering wick" is a flux-impregnated copper braid that wicks molten solder, leaving a clean hole. You can buy desoldering wick at All Electronics (https://www.allelectronics.com/item/swk-3/de-soldering-wick/1.html).
- A "solder sucker" is another option. You depress a spring-loaded plunger, melt the solder with your iron, then press a button to release the plunger and suck the solder away. All Electronics sells a solder sucker (https://www.allelectronics.com/item/swk-3/de-soldering-wick/1.html).