Powering the Blunami DCC Controller from AC Track Voltage

The Blunami[1] DCS controller card by Soundtraxx is a viable, lower cost and more flexible alternative to Lionel TMCC^{tm} or MTH DCS^{tm} for command control of S-gauge and many 3-rail O model railroad locomotives. It is particularly well suited for converting pre-TMCC, pre-DCS diesel models to command control. The challenge to be overcome is converting AC track power to the DC power that the Blunami card requires. Specifying components for a suitable AC>DC converter is not complicated and such a converter is easy to assemble, if one has basic soldering and wiring skills.

There are three major steps in planning the AC>DC converter needed to implement a Blunami upgrade:

1. Characterize the motor(s) and locomotive to be powered, by measurement;
2. Determine the ratings for the full-wave bridge rectifier, filter/smoothing capacitor, and, if needed, converter/regulator;
3. If twin can motors are used, determine whether to wire them in series or parallel.

This guide not only describes these steps, but also includes several Appendices which provide measured motor data, design objectives, AC>DC converter theory of operation, and example conversions.

A. Defining the Locomotive's Voltage and Current Needs

To complete the design parameters for the AC to DC converter, you need to know the locomotive's limiting-case operating parameters: (1) minimum motor voltage needed to achieve the desired speed under load, (2) maximum current draw when hauling a long train uphill, and (3) motor stall current.

These should be determined experimentally, unless data are readily available for locomotives and/or motors similar to those you want to convert. Results will be best if an adjustable DC power supply capable of 18V at 10A (or more) is available, but a variable AC track power transformer can be used if not. Modern power packs for DC-powered trains can also be used, if their current ratings are high enough.

1. Minimum Motor Voltage (V_{min}):

The voltage required for the locomotive to pull a long freight train at the desired maximum speed, uphill (or, alternatively, around the sharpest mainline curve if there is no grade) will define the regulator output voltage and, if twin motors are used, their wiring. Set up the longest freight train that you expect the locomotive to normally pull, with cars of typical weights. Then run the locomotive and freight train around your layout and up the steepest mainline grade or around the sharpest mainline curve, if you don't have any grades.

If you do not have an adjustable DC power supply, monitor the AC track voltage using the transformer's built-in voltmeter or an external multimeter (true-RMS digital is preferred) and adjust track voltage to achieve your desired maximum speed through all sections of the mainline. Note the highest voltage indicated by the meter.

If an adjustable DC power supply is available, then disconnect the existing (often DCRU/PS1) electronics from the track pickup rollers and motor. Temporarily connect the rollers and chassis

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common directly to the motor(s) and connect the DC power supply in place of your normal track power transformer. Then raise the DC power supply's voltage to get the train running up to the maximum desired speed. Monitor the DC track voltage using the voltmeter on the power supply or an external multimeter as the train ascends the steepest mainline grade or goes around the sharpest mainline curve, at your desired maximum speed. Note the highest indicated voltage.

A twin-motored freight diesel model with the popular Mabuchi RS-385PH can motors needed 8VDC across the paralleled motors to achieve a maximum speed of 40-45 smph, uphill, pulling 15 cars. To achieve 50-55 smph, 9VDC was needed. This voltage is referred to as V_{min} later.

2. Maximum Running Current (I_{max}):

The current drawn by the locomotive when pulling a long freight train at the desired maximum speed, uphill (or, alternatively, around the sharpest curve if there is no grade) defines the normal maximum current that the AC-DC converter and motor drive electronics must deliver. Use the same test train as that used to determine necessary motor voltage.

If you do not have an adjustable DC power supply, then run the locomotive and freight train around your layout as in the necessary voltage test. Monitor the track current using the meter built into the track power transformer or an external multimeter (true-RMS digital is preferred) connected in series with the center rail track power feed from the transformer. Adjust the track voltage to achieve your desired maximum speed. Note the highest current indicated, as the train ascends the grade or goes around a sharp curve. This current measurement includes locomotive lighting and the "overhead" of whatever electronics are presently in the locomotive, so it will be slightly greater than that of the motor(s) alone. ¼ Ampere is a good average approximation of the non-motor current drawn.

If an adjustable DC power supply is available, leave the locomotive wiring and track power as it was for the necessary voltage test. If the DC power supply does not have a current meter, connect a multimeter in series with the center rail power feed. Then raise the DC power supply's voltage to get the train running up to the maximum desired speed. Monitor the DC track current as the train ascends the steepest mainline grade or goes around the sharpest mainline curve, at your desired maximum speed. Note the highest current indication seen. This current will be called I_{max} later.

The twin-motored freight diesel model noted previously drew slightly less than 2 Amperes DC when pulling 15 cars up a 3% grade. The Mabuchi RS-385PH can motors were paralleled.

3. Stall (Locked Rotor) Current:

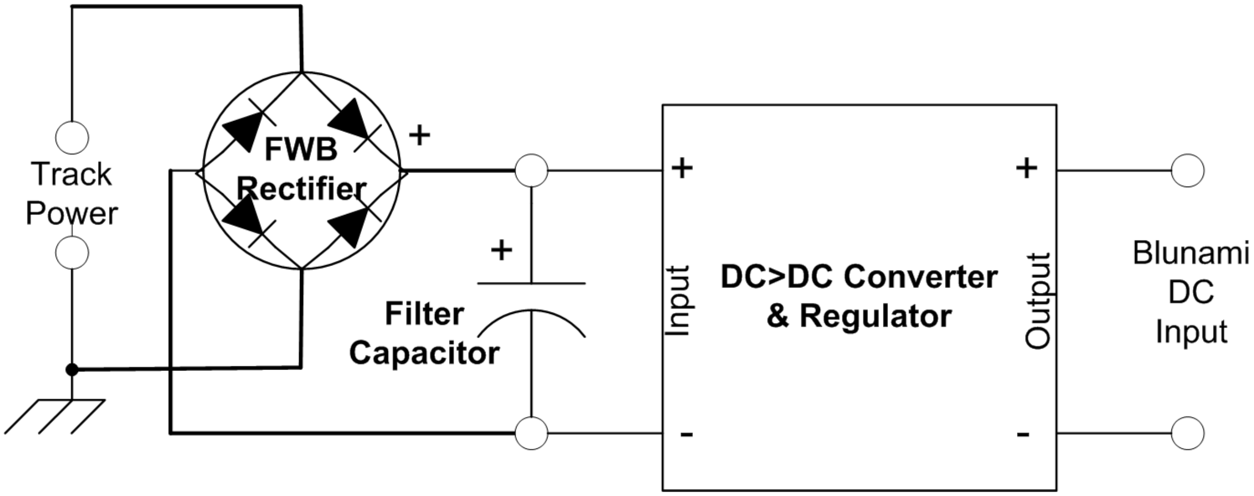
In this test, the motor(s) is/are physically stopped when fed with the necessary motor voltage determined earlier and the current then drawn is measured. You don't need a test train – this test can be done on the workbench or layout, using only the candidate locomotive.

Use the same track power source and current measurement method as in the previous test. Can motors with flywheels are the easiest to stall, but imparting friction to the driving wheels or pushing down hard on the locomotive while atop track will accomplish the same thing. Note that the motor voltage may sag when the motor is stalled, in which case you should increase the voltage so that the necessary motor voltage, previously determined, exists when the motor is stalled. This issue is most pronounced when using a postwar Lionel AC transformer and least when using a stiff DC power supply. Note the current seen with the motor stalled.

Several late-90s diesel models with Mabuchi RS-385PH twin can motors drew around 4A per stalled motor, as detailed in Appendix I.

B. AC>DC Conversion Principles

Converting AC to DC power involves (1) a full-wave bridge (FWB) rectifier, (2) a smoothing/filter capacitor, and, if necessary, (3) a DC>DC converter/regulator to provide the proper voltage at the point of supply to the Blunami card. All of these items are available off-the-shelf, but no fully integrated sets at the 12-20V AC level common in model railroading have been reported within the hobbyist community. The drawing below illustrates these components and their connections.



If track voltage is limited to 16V or less and only a single motor or two wired in parallel will be used, it is possible to omit the converter/regulator. This is not recommended for layouts where DCS and TMCC equipped locomotives will regularly be run.[2] A significantly larger smoothing/filter capacitor will be needed than with a DC>DC converter/regulator in use.

The FWB provides basic rectification of AC to pulsed DC. The pulses are smoothed out by the filter capacitor, to keep instantaneous DC voltage well above zero and minimize 120Hz ripple. The DC>DC converter/regulator may reduce or increase the voltage, maintaining it at a near-constant voltage, regardless of variations caused by track and wiring resistance variations and other anomalies. In the more likely voltage reduction case, it also keeps controller input voltage from exceeding the maximum input rating of the Blunami card.

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[2] Few S-gauge will be running TMCC/Legacy locomotives, so, for most S gauge situations, the track voltage will be set below 16V and the DC>DC converter/regulator is unnecessary. If the Blunami 2200 card is used, track voltage should not exceed 14VAC, due to its 23V maximum DC input rating.

C. Component Ratings Recommendations

Here are the specifics of component and assembly ratings needed for onboard AC to DC voltage conversion. None of this is complicated.

1. Full-Wave Bridge Rectifier: The peak inverse voltage rating should not be less than 3 times the nominal track voltage. For 18V track voltage, that's 54 Volts. Accordingly, the next "standard" size up, 100V, is recommended. Current rating should be twice that of the Blunami card being used: 4A minimum for the 2200, 8A minimum for the 4408. This rating headroom is to ensure adequate peak current capability when the filter/smoothing capacitor is charging.

2. Filter/Smoothing Capacitor: The working voltage should be no less than 1½ times the nominal DC voltage. The closest standard rating, assuming 18VAC on the rails, is 35V.

   If a DC>DC converter/regulator is not used, the capacitance value must be sufficient to keep ripple from causing voltage minima that are too low. The necessary capacitance can be determined from the following, empirically-derived formula:

   $$C = 20{,}000 I_{max}/V_{min}$$

   Where: C = capacitance in µF
   I_{max} = full load motor current
   V_{min} = minimum motor voltage for desired speed

   For the example noted above, the minimum motor voltage is 9V and the full-load motor current is 1.8A (motors wired in parallel), the calculated capacitance is 4000µF, with 3900µF being the nearest standard value. If the motors are connected in series, the voltage doubles and current halves, reducing the required capacitance to 1000µF.

   If a DC>DC converter/regulator is in use, the motor voltage will usually be less than the rectified and filtered track voltage. The filter/smoothing capacitor is located before the converter/regulator, so its value is dependent upon motor power, not motor voltage. It is assumed that a constant track voltage near 18V will be provided, typical of layouts where DCS and TMCC equipped locomotives are in use. With a DC>DC converter/regulator in-circuit, the capacitance value is computed from this formula:

   $$C = 48\, V_{min} I_{max}$$

   Where: C = capacitance in µF
   I_{max} = full load motor current
   V_{min} = necessary motor voltage

   For the example of a diesel with two can motors, the calculated minimum capacitance is 778µF, below that for the no-regulator case noted above, especially if the motors are wired in parallel. However, the value of any capacitor at the input of the converter/regulator must be subtracted to obtain the net capacitance value to be used. So, if the onboard capacitor is 100µF, the minimum filter/smoothing capacitance would be 678µF, with 680µF being the closest standard value.

   Choose a capacitor with a long hours rating and low ripple or ESR. If the calculated value is more than 10% above a standard value, use the next higher standard capacitance rating. Increasing capacitance a step or two above the calculated value is sometimes helpful.

3. DC>DC converter/regulator: Installations for locomotives that will be powered from constant track voltage around 18V, which is typical of layouts hosting DCS and TMCC locomotives, will involve a lower input voltage to the Blunami card than voltage across the smoothing/filter capacitor. This reduction is best achieved with a "buck" converter, with input voltage rating of not less than 30V and output voltage range of 10-20V or wider. Current rating should not be less than that of the Blunami card being used – 2A for the 2200 card or 4A for the 4408 card. If a "boost" converter is used to ensure adequate voltage with series-connected motors, its input and output ratings should be at least 30V and current rating no less than that of the Blunami card used. The converters pictured below can be obtained from Amazon, envistiamall.com, and other sources.

D. Single Motor Installations

Single motor installations will not need the full amount of track voltage at the Blunami card input. Reduced voltage can be obtained from a variable output voltage transformer (e.g., classic Lionel ZW) or the output of an onboard DC>DC regulator/converter. Most can motors used in contemporary S and O gauge locomotive models are configured for 12VDC maximum operation. So there seldom will be a reason to supply the Blunami card with more than 12-14VDC, when a single motor is in use. Once the conversion is finished, Soundtraxx recommends entering the Blunami input voltage into CV 215.

If DCS and/or TMCC locomotives are to operate on the same tracks as the Blunami-controlled locomotive, the track voltage will typically be set to around 18-19VAC. The most efficient means of DC voltage reduction/regulation is via a DC>DC "buck" converter. These regulators use high-frequency switching to reduce the filtered FWB DC voltage to the converter's output set point, with minimal internal power dissipation. Linear voltage regulators vary the resistance of a series pass transistor, with significant power lost to device heating, so they should be avoided. Here's a picture of the cheap Chinese 5A buck converter that was used in generating the data presented and in the Blunami conversion described in the Appendices. It measures only 54x24 mm (2-1/8x1").[3]

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[3] A caveat is in order here, since anything larger than a mid-sized can motor will have a stall current exceeding the Blunami 4408's 4A rating, as will two medium-sized can motors wired in parallel. The Blunami card has internal current limiting to prevent overload, so it is possible, with caution, to drive motors with high stall currents if the maximum uphill running current is 3A or less. It's the modeler's

E. Dual Can Motor Wiring

As previously noted, the medium-sized Mabuchi RS-385 can motors used in many MTH and imported Weaver diesels from the mid-1990s generally achieve realistic maximum freight train speeds at 8-9VDC and consume 15-20W when going uphill with an average 15-car train. Their stall currents at these voltages are around the rated current of the Blunami 4408 card, 4A (see Appendix I). Particularly for freight service, these motors may be wired in series, with the DC>DC converter/regulator output set to 18V (and entered into CV 215), respecting the stall current rating of the Blunami card while performing well.

However, that may not be enough voltage to achieve higher passenger train speeds. There are three ways to approach resolution of this problem, (1) wire the motors in series, use a "buck" converter, and set the voltage 2-3 volts higher than for the freight locomotive case; (2) wire the motors in series and use a "boost" converter to ensure reliable voltage in the 22-23VDC range at the Blunami card input or (3) wire the motors in parallel, with the same considerations as for the single-motor case noted previously.

The modeler is faced with a choice of less-than-ideal situations. Wiring the motors in series and setting the "buck" DC>DC converter/regulator to 21-22V results in the input to the Blunami card not being pure DC, although quite close thereto. If the "boost" converter approach is taken, there's little headroom between the peak DC input voltage to the Blunami card and its 26V limit. This is because the boost converter "fills in" voltage excursions below its voltage set point, but follows voltage excursions above its set point.[4] An inexpensive Chinese "boost" converter is shown below. If the paralleled motors approach is taken, the stall current (total of 2 motors) exceeds the Blunami 4408 card's rating.

The obvious solution to this conundrum is to use a "boost" converter to raise the voltage to 25VDC, followed by a "buck" converter/regulator to reduce it to 22-24VDC. But that seems a bit too complicated – and burns up around 15-20% of the total power in converter heating.

If setting the output voltage of the "buck" converter to 19-22V range permits the desired speed to be obtained, that is the preferred approach. If that voltage is not sufficient, then parallel connection of the motors and a lower (12-14V) output voltage from the "buck" converter should be considered. Note that,

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tolerance for risk that will drive the decision to use Blunami controller cards with larger or paralleled can motors. Maybe Soundtraxx will eventually release a higher-current Blunami card?

[4] While the Blunami card has internal voltage limiting, approaching the maximum isn't recommended.

for the 18V track voltage of layouts running DCS and TMCC locomotives, the filter/smoothing capacitor value is fixed, regardless of converter output voltage.

F. Some S Gauge Comments

My home layout is 3RS O gauge, but I'm also involved with my club's traveling S gauge layout and equipment. My limited experience with can-motored S gauge locomotives, to date, is that you can take typical O gauge performance current/power data and divide it by two. The single can motor in an American Models (AM) S gauge diesel has a stall current of 2A and draws around 0.5A when pulling an average-sized train. AM's Pacific steamer has a stall current around 4A. So the latter would need the 4408 card, but the former could get by with the 2200 or PNP8 modules.

Space for electronics does not appear to be a particular issue for S gauge steam engines. But diesels are another matter. The American Models diesels have a horizontally-mounted can motor powering both trucks via large weight/gear assemblies. The trucks and connecting shafts to the motor significantly impact space for components, especially a sound speaker. There's only ¾" clearance above the can motor and around 5/8" clearance above the rear truck assembly in the GP-35 model, with about an inch of width to work with under the hood. The main challenge in converting these engines to Blunami control appears to be component mounting. Because the fuel tank attaches to a weight located below the can motor, there doesn't appear to be any room for a speaker in it. Supports would need to be fabricated to mount any components above the rear drive shaft and rear truck. However, if the layout where the locomotive will be used does not have any Lionel American Flyer Legacy or FlyerChief locomotives, the DC>DC converter/regulator can be eliminated if the track voltage is held at 14VAC[5] or less, simplifying the components and space needed. The challenges of these engines may be explored further as time permits.

G. Installation Cautions

The "common" bus on the Blunami card and the preceding DC>DC converter/regulator is not at locomotive chassis potential. Any connection between that bus and the locomotive chassis will result in high AC current flow and failure of the converter/regulator and Blunami controller cards. Likewise, neither of the motor outputs from the Blunami card are at chassis potential. After making all connections to the Blunami card and before applying power, check resistance between each connection and the locomotive chassis using a digital multimeter. It should read in at least kilohms, if not meghohms. Connections to motors, speakers, etc. should be covered by heat-shrink tubing after connections have been soldered in order to prevent inadvertent connections to chassis potential.

If feasible, the full-wave bridge rectifier should be secured to the base plate of the locomotive, using nylon hardware and heat sink grease, to dissipate heat. If the rectifier has an exposed metal plate on one side, check continuity between that plate and each of the four leads. If resistance is minimal between the plate and any lead, a mica insulating washer will be required between the rectifier and the base plate.

Unless you plan on replacing incandescent bulbs with LEDs during the locomotive conversion process, it is wise to measure the voltages on those bulbs before dismantling the original locomotive electronics. Some operate at lower-than-track voltages, such as 6V, and may be burned out if appropriate current-limiting resistors are not used in their circuits.

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[5] Assuming use of the Blunami 2200 card

Appendix I

Measured Motor Currents

Mabuchi RS-385PH Motor

No-Load Can Motor Currents in Amperes

DC Supply	**Weaver Sharknose**		**MTH GP-9**		**MTH PA-1**		
Voltage	Motor 1	Motor 2	Motor 1	Motor 2	Motor 1	Motor 2	Average
5	0.26	0.24	0.22	0.20	0.19	0.23	0.22
6	0.27	0.25	0.22	0.21	0.19	0.24	0.23
7	0.29	0.23	0.23	0.22	0.20	0.32	0.25
8	0.30	0.24	0.24	0.23	0.21	0.26	0.25
9	0.32	0.25	0.22	0.23	0.22	0.36	0.27
10	0.33	0.26	0.23	0.24	0.22	0.48	0.29
11	0.34	0.27	0.23	0.25	0.23	0.48	0.30
12	0.35	0.27	0.23	0.26			0.28

Can Motor Stall Currents in Amperes

DC Supply	**Weaver Sharknose**		**MTH GP-9**		**MTH PA-1**		
Voltage	Motor 1	Motor 2	Motor 1	Motor 2	Motor 1	Motor 2	Average
5	2.2	1.8	2.3	2.4	2.3	2.0	2.2
6	2.6	2.5	2.9	2.9	2.7	2.2	2.6
7	3.5	3.0	3.3	3.3	3.5	3.0	3.3
8	3.9	3.4	3.7	3.9	3.8	3.2	3.7
9	4.5	3.8	4.1	4.2	4.4	3.9	4.2
10	4.5	5.0	4.4	4.9	5.0	4.2	4.7
11	4.8	5.3	5.6	5.3	4.8	4.8	5.1
12	5.0	5.2	6.0	5.1			5.3

DC power provided by 18V 10A laboratory-grade regulated power supply.

Appendix II

AC>DC Converter Design Objectives

A. Interface Goals

The overriding goal in designing a AC-to-DC power converter is to ***do no harm***. You don't want to smoke that controller card that you just spent $200ish for. Nor do you want to burn up the locomotive's motor or its ancillary features, such as lighting, electrocouplers, etc. Here are the specific objectives of interface design:

- Power the DCC controller card with the most practical approximation of constant DC voltage.
- Prevent excessive voltage at the DCC controller power input terminals
- Avoid exceeding the DCC controller's stall current rating with motor shafts locked.
- Provide sufficient voltage to operate the locomotive at your desired maximum speed.
- Provide sufficient current to hold the desired speed uphill with maximum typical train weight.
- Ensure reasonable speed consistency with typical track voltage variations.
- Occupy minimum space within the locomotive or tender body.

B. Design Boundary Principles

Track voltage will be maximum when the locomotive is nearest the AC power source and idling. The peak rectified voltage (not the averaged DC value) at the input to the motor driver and sound electronics card should not exceed the card's voltage rating under that condition.[6] And having at least 10-20% of "headroom" between normal peak voltage and driver/sound board rating is a recommended practice, to accommodate line voltage variations that may occur due to commercial power grid loading and/or faults. Many O gauge model railroads using remote command control systems operate at nominal track voltages in the 18-19 VAC range. The peak rectified DC voltage for 18V will be around 24½V, above the 23V input rating of the Blunami 2200 card and leaving only 1½V of headroom below the Blunami 4408 card's 26VDC input rating, insufficient to afford appropriate "headroom".

The output voltage of the controller card should be sufficient to achieve the maximum speed desired for the locomotive being powered. As noted above, it is necessary to determine this voltage experimentally, since each can motor type has a different voltage-vs-speed relationship. That output voltage determines the minimum input voltage for the card, which should be a volt or two higher than what the locomotive requires, to ensure smooth speed control.

The stall (stopped shaft or locked rotor) current of the locomotive's motor(s) should not exceed the rating of the controller card, as specified in the Blunami instructions. The 4408 card has a stall current limit of 4A, while the 2200 card has a limit of 2A. The popular Mabuchi RS-385PH medium-sized can motors have a locked rotor current near 4A each, at a voltage sufficient to achieve the maximum desired speed, and therefore are compatible if wired in series. Stall current, too, must be determined experimentally, as described above.[7]

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[6] While the Blunami card has internal voltage limiting, approaching the maximum isn't recommended

[7] The Blunami 4408 controller card has internal current limiting and, therefore, the motor stall current can exceed the card's rating as long as current drawn in normal train operation doesn't approach the 4A rated limit. Using that card with a motor having a stall current above 4A is a matter of risk tolerance by the prospective user

The normal maximum current drawn by the locomotive, which occurs when it is running uphill at the maximum desired speed, with a train of the maximum length and weight one ordinarily expects to run, should lie well within the controller card's ratings. Not exceeding half of the stall current rating is recommended, so that there is sufficient headroom in the motor driver to maintain good speed control. The medium-sized can motors noted above met that criterion easily, drawing ¼ of the Blunami card's maximum current when pulling a 15-car train up a 3% grade, wired in series.

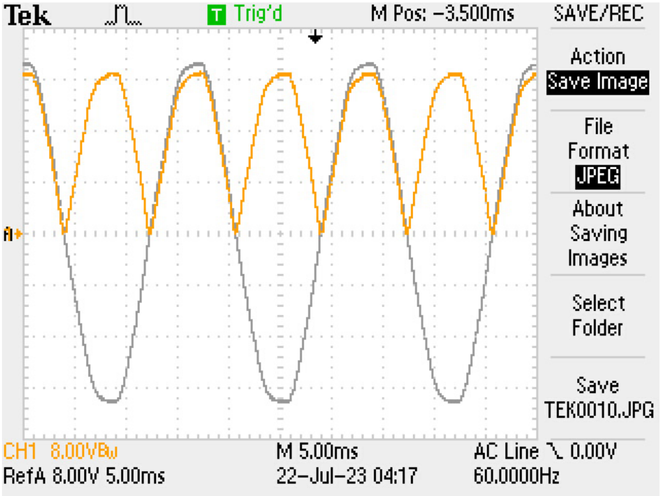
Rectified AC voltage is not pure, constant, DC voltage. It inherently has some degree of ripple, which occurs at a 120 Hz rate when full-wave rectification is used. The ripple voltage minimum is a function of the loading of the rectifier and the size of the smoothing/filter capacitor used. For reliable operation, that minimum should not fall below the voltage needed for the maximum desired locomotive speed, up a grade, with the heaviest train that one expects the locomotive to haul. Put another way, the converter/regulator input voltage minima should remain above the maximum output voltage desired, in the case of a regulator that reduces the filtered DC voltage to the desired controller card input voltage. This limit is not similarly applicable when the regulator increases the DC voltage above the filtered value, but is not irrelevant.

Appendix III

AC>DC Converter Theory of Configuration

A. Basic Rectification

The AC track voltage is rectified to DC using the full-wave bridge rectifier (FWB). The output of the FWB alone is compared to its input in the waveform screen capture below. No filter/smoothing capacitor was connected during this test.



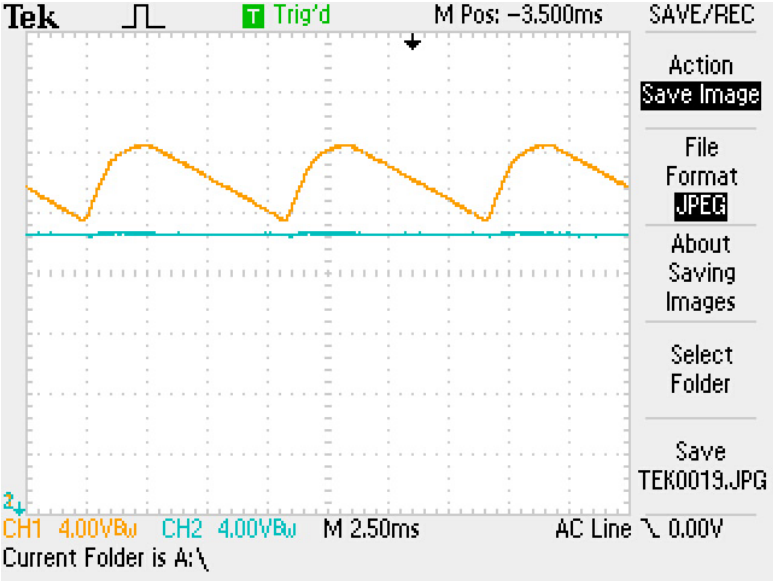
CH1 8.00VBw M 5.00ms AC Line 0.00V
RefA 8.00V 5.00ms 22-Jul-23 04:17 60.0000Hz

The gray trace is the AC input; the orange trace is the DC output. The vertical scale is 8V/division, with 0V reference at the center. The rectification of the negative cycle of the input AC waveform is obvious in this screen capture. DC output is not a constant DC voltage, but rather a one that varies between 0 and 25.3V. Direct connection of the rectifier output to the Blunami controller card input would not provide a true, constant DC voltage supply. Note that the gray trace reaches a higher maximum voltage (26.6V) than does the orange trace (25.3V). This difference is caused by the inherent voltage drop across the rectifier diodes.

AC power was sourced for this and all following measurements from a Lionel Powerhouse^{tm} 180 transformer, which has an open-circuit output voltage of 19V and a loaded voltage around 18V. The rectifier was loaded by a 20 Ohm power resistor, which approximates two can motors wired in series.

B. Filter/Smoothing Capacitor

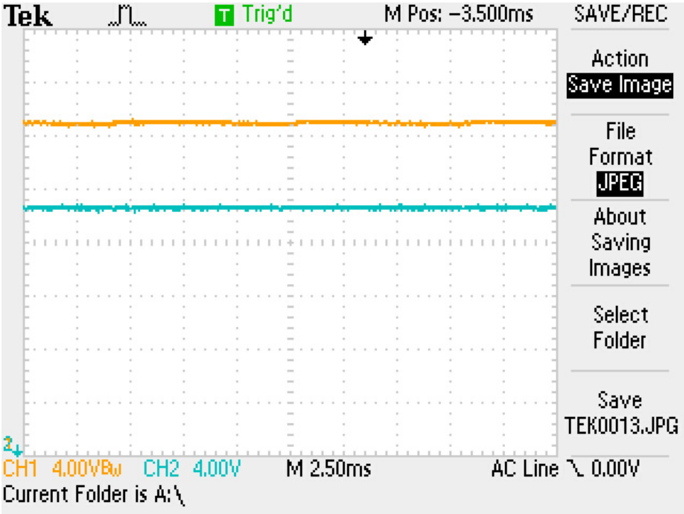
Addition of this capacitor "fills in" the troughs of DC voltage illustrated by the orange trace above. In the next waveform screen capture, the 0 Volt reference is the bottom line of the screen and the vertical scale is 4V per large division. The orange trace is the input to the converter/regulator, following the capacitor. Maximum voltage is 24.3V and minimum is 19.4V. The pulse repetition rate is 120Hz, twice the AC line frequency, 60Hz.



C. DC>DC Converter/Regulator

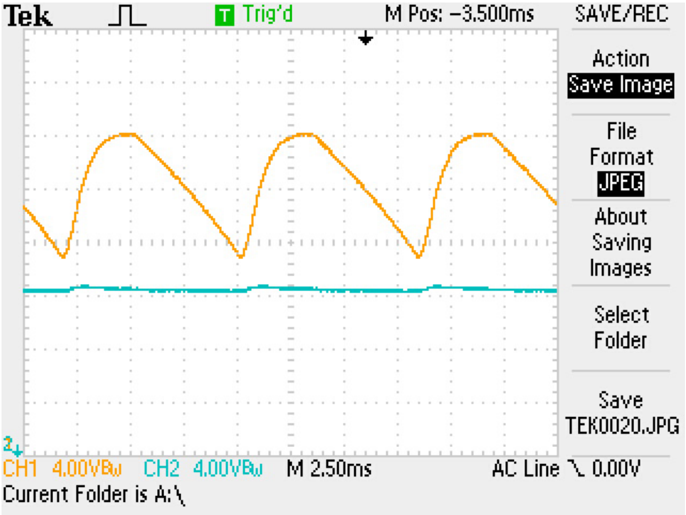
In this example, the desired input voltage to the Blunami card was 18VDC. The trough of the pulsed DC output after the filter/smooting capacitor is 19.4V. The DC>DC converter/regulator reduces the pulsed DC voltage to a constant 18V, as shown by the blue trace above, recorded from the output of the converter/regulator. It is essentially constant, because there exists 1.4V of headroom between the desired output voltage and the minimum input voltage. The converter/regulator ensures that (a) the 26V input rating of the Blunami card will not be exceeded and (b) a truly constant DC voltage is provided to that card's power input terminals.

Next, let's take a look at what happens when the locomotive is idling and drawing minimum current from the converter, rectifier, and track.



The reduced load on these circuit elements increases the maximum voltage at the rectifier output (orange trace) to 24.6V, only 1.4V below the 26V maximum voltage input rating of the Blunami controller card and 0.3V higher than that for the 20 Ohm load case. It takes only a 6% rise of the incoming AC line voltage to cause the Blunami card's DC input rating to be exceeded, if there's no converter/regulator protecting it. But the voltage leaving the converter/regulator remains near 18V, protecting the Blunami card. This is why including a DC>DC converter/regulator is recommended for all situations and is considered mandatory for AC track voltages above 16V.

In some situations, it may be desirable to connect twin can motors in parallel. In that situation and the single-motor case, the required voltage at the Blunami input terminals will be considerably lower. As an example, let's consider the same dual can motor situation as used above, but with the motors wired in parallel. It was assumed that 10V is needed to achieve sufficient locomotive speed under load with approximately 2A drawn, or 20W. This screen capture compares the rectifier/filter output to that of the converter/regulator set to 12V. A 5 Ohm power resistor was used to simulate the locomotive load. There was no change to the filter/smoothing capacitor value, because its rating was determined from the rated power, not voltage/current, and a constant 18-19V track voltage was assumed.

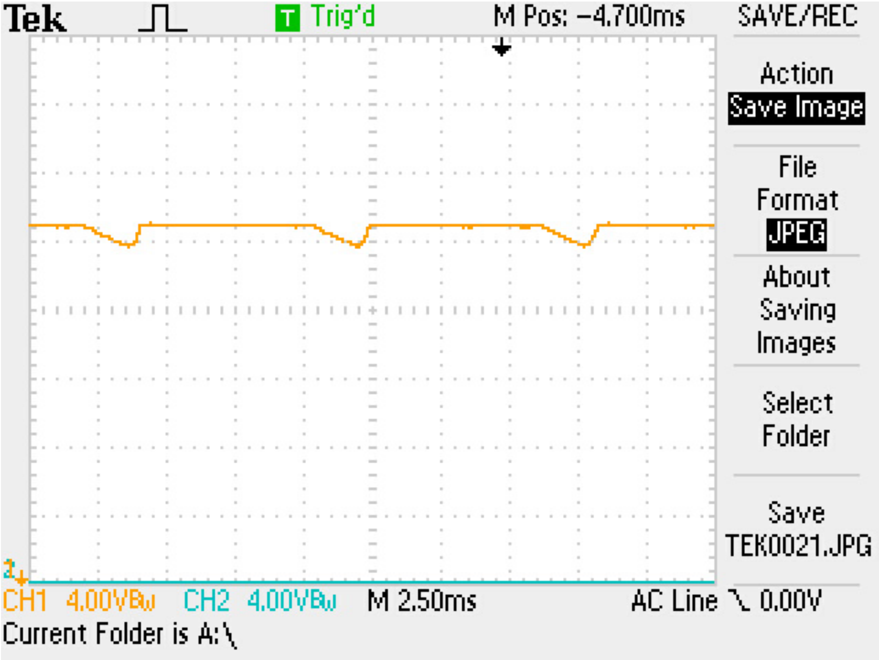


The orange trace is the input to the regulator, which varies from a minimum of 15.0V to a maximum of 24.0V. The blue trace is the converter/regulator output, which is nearly constant at 12V. Greater voltage variation at the DC>DC converter/regulator input than the earlier, 18V case, can be tolerated because of the lower output voltage at its output. The 12V output set point of the DC>DC converter/regulator provides 2V of headroom above the minimum desired motor voltage, to achieve better top-end speed control than a smaller difference.

D. Increased Voltage for Dual Can Motors

A DC>DC converter/regulator output of 18VDC may not be sufficient for series-connected can motors to achieve passenger train speeds. There are three ways to approach resolution of this problem, (1) wire the motors in series, use a "buck" converter, and set the voltage 2-3 volts higher than for the freight locomotive case; (2) wire the motors in series and use a "boost" converter to ensure reliable voltage in the 22-23VDC range at the Blunami card input or (3) wire the motors in parallel, with the same considerations as for the single-motor case noted previously.

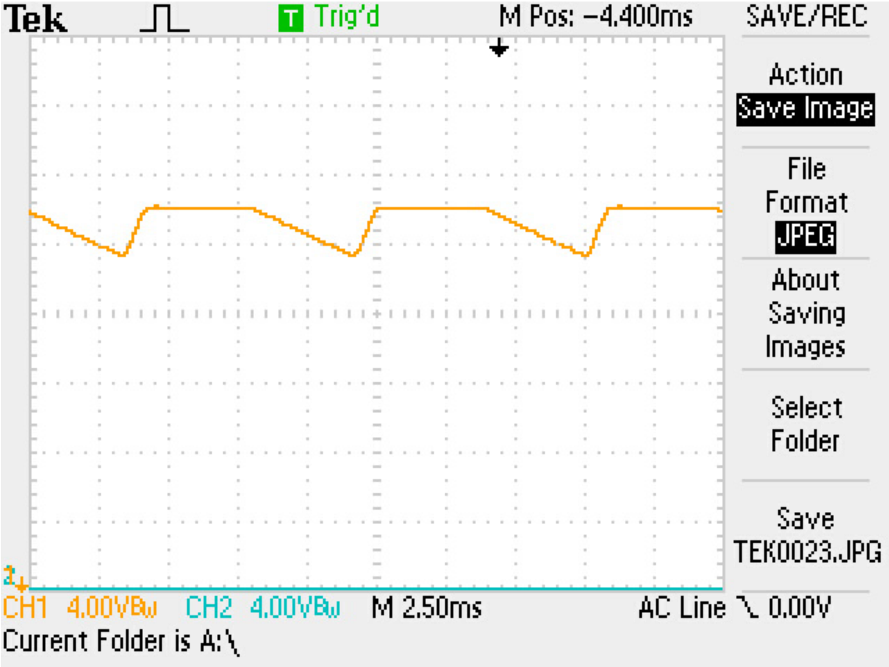
Let's look at the first option, series motors with a higher "buck" converter DC output voltage. Referring to the waveform plot at the bottom of page ii of this Appendix, the DC output from the converter/regulator is pure 18VDC. Here's the waveform, which is no longer pure DC, when the average output is raised to 20VDC and the filter/smoothing capacitor increased from 680µF to 1000µF:



CH1 4.00VBw CH2 4.00VBw M 2.50ms AC Line ↘ 0.00V
Current Folder is A:\

The voltage sags below its maximum for 0.8 horizontal divisions of a 3.4 division cycle, which is just under 25% of the time. The sag amplitude is not quite 10%. Given the limited degree of sag in time and level, the impact on locomotive performance is likely to be minimal, assuming that 10VDC per motor is sufficient to achieve respectable passenger train speed.

Now let's increase the maximum voltage to 22V, which will increase the time duration and amplitude magnitude of the sag, with a small increase in motor power consumption



CH1 4.00VBw CH2 4.00VBw M 2.50ms AC Line ↘ 0.00V
Current Folder is A:\

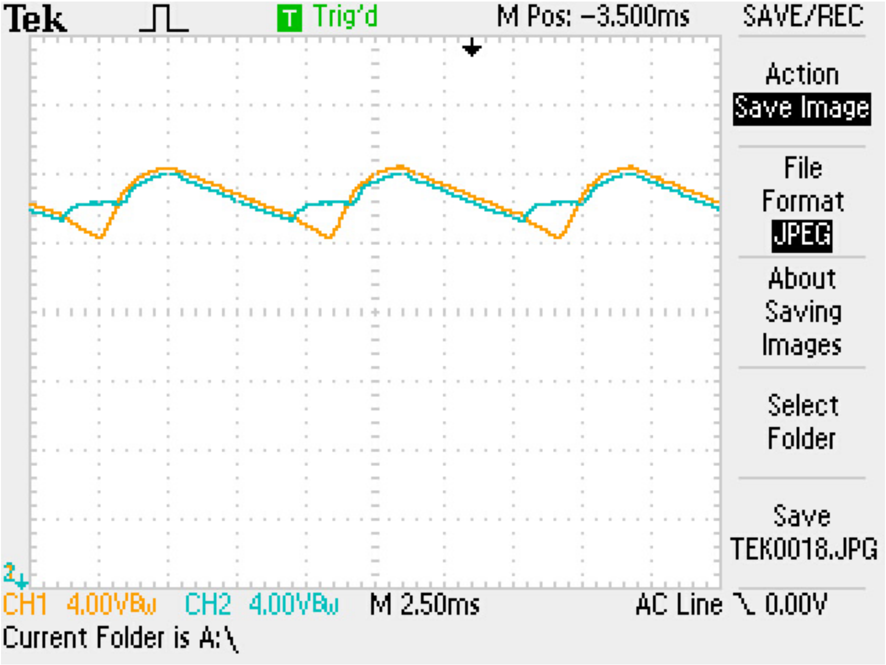
Sag time increases to 1.6 divisions (nearly 50%) and around 12% in amplitude.

It should be kept in mind that the simulated motor power consumption is based on a 13-16 car freight train. A passenger train of 7 or fewer cars would consume less power and, therefore, would have less sag, in both amplitude and time.

The advantage of wiring the motors in series and increasing the DC>DC converter/regulator output is that there's protection from excess input voltage to the Blunami card, yet higher voltage available to support passenger train speeds. This is the configuration adopted for my second Blunami conversion, a MTH passenger GP-9 model.

Next, let's look at the use of a "boost" DC>DC converter to provide higher DC voltage to the input of the Blunami card. Here's a picture of an inexpensive, 5A Chinese converter, which measures 60x25mm.

Its behavior is clearly shown in the following screen capture, which shows the boost converter input and output voltages at a 22VDC output set point, with a 24W simulated load:



M Pos: –3.500ms

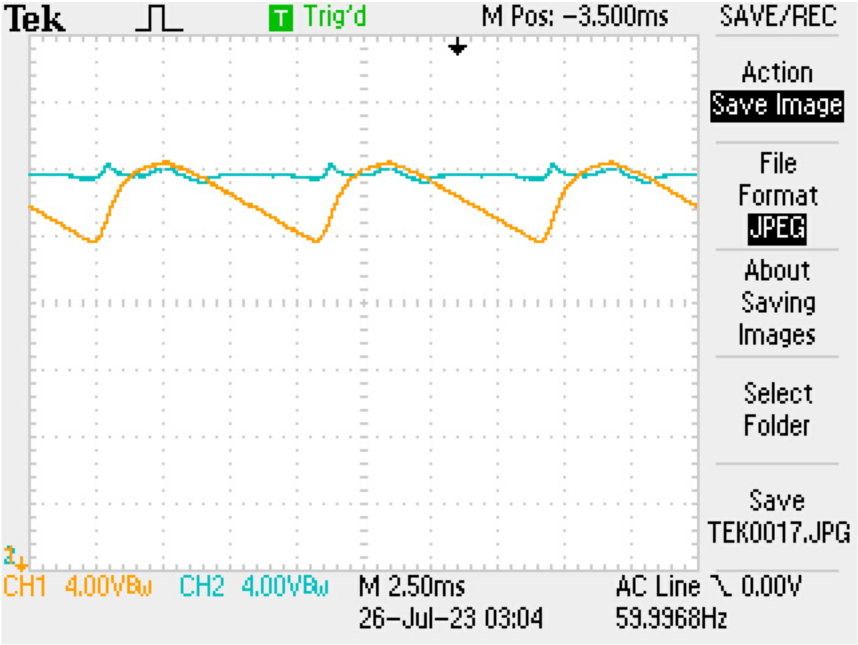
File Format JPEG

CH1 4.00VBw CH2 4.00VBw M 2.50ms AC Line ⟍ 0.00V

Current Folder is A:\

Like the earlier images, the vertical scale is 4V per large division. Input voltage is shown by the orange trace; output by the blue trace. You can see that the output voltage follows the input from its maximum down to around 21.1V. The boost function then raises the voltage to 22V, but when the input voltage exceeds that level, the output voltage tracks the input voltage once again. The maximum output voltage reaches 23.7V, 2.3V (9%) below the maximum input rating of the Blunami card. The maximum input voltage to the DC>DC converter/regulator is 24.2V.

The next screen shot shows the same DC>DC converter/regulator input/output voltage comparison for a 23VDC set point (26W simulated load).



The input voltage reaches a maximum of 24.2V. Output maximum is 24.3V at the little spike, with its minimum at 22.9V, corresponding to the input voltage minimum point in time (horizontal scale). Overall, the output varies less than the 22V case, since the boost converter is active over more of the input waveform cycle. But the headroom to the card's DC input voltage limit has been reduced to 6%. So the "boost" DC>DC converter, alone, doesn't protect the Blunami card from excessive DC input voltage.

As noted above, wiring the motors in parallel eliminates the voltage sufficiency issue, but at the expense of the total motor stall current being twice the Blunami card's rating. A degree of risk is involved, which some modelers might accept. But that approach isn't recommended unless the "buck" DC>DC converter/regulator 20-22VDC output approach doesn't ensure sufficient train speeds.

Appendix IV

The Blu Shark Project

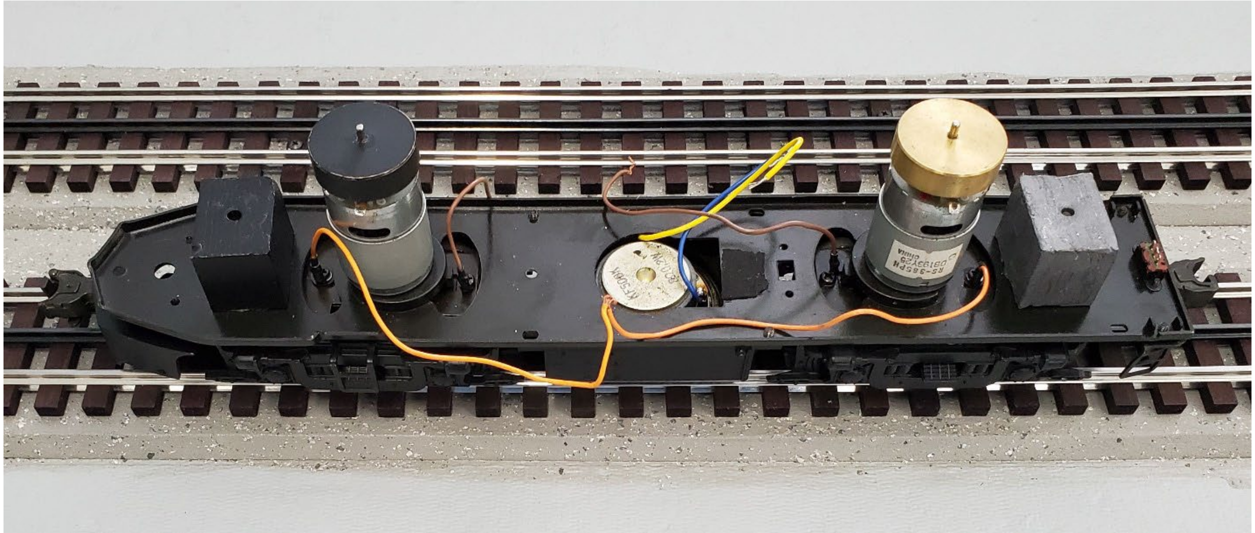
My first locomotive conversion to Blunami control was a Weaver Baldwin Sharknose diesel model from the mid-1990s. It came with two medium-sized Chinese can motors, a QSI DCRU reverse unit, and elementary QSI horn/bell sound card. With plenty of interior space for the AC>DC converter and Blunami card, it seemed like an excellent candidate for the first conversion.

A. Components

1. Full-Wave Bridge Rectifier: A Diodes, Inc. GBU-1001 bridge, with a peak inverse voltage rating of 100V and 10A continuous current rating, was chosen for this project.
2. Filter/Smoothing Capacitor: A Panasonic 1000µF, 50V radial lead electrolytic capacitor was used. While a smaller capacitor was feasible, part of this project included testing the locomotive without a DC>DC converter/rectifier, which necessitated a larger capacitor to keep voltage minima above 18V.
3. DC>DC Converter/Regulator: A Chinese "buck" downconverter, based on the XL4015 IC and rated at 5A, was obtained from envistiamall.com and installed in the model.

B. The Nude Shark

The following picture shows the Weaver diesel with the original electronics removed, prior to installation of the AC>DC converter and Blunami controller card. The speaker remains in the fuel tank space.

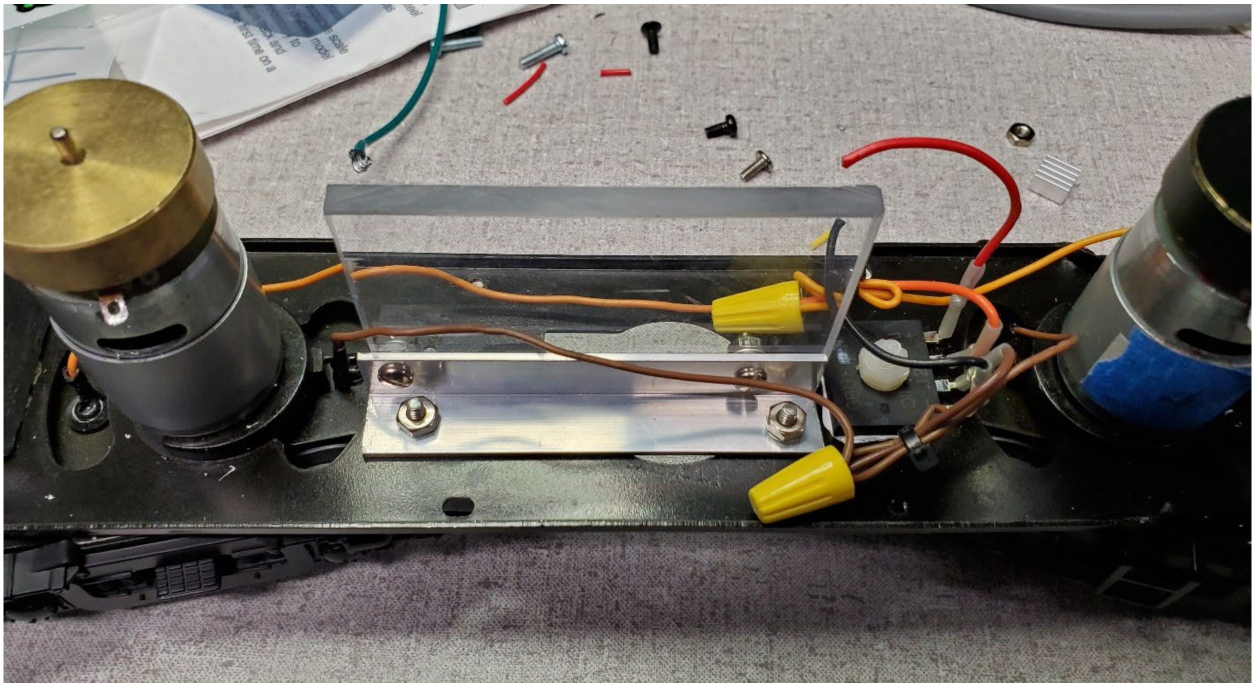


C. Initial Track Test

The Blunami card was temporarily installed in the Shark, along with the rectifier/filter arrangement described above, but without the DC>DC converter/regulator. The Blurail app was loaded on my iPad. The engine came to life and was readily controllable on the workbench. It was moved to my layout, where it behaved predictably. It had no problem pulling the 15 car train around the layout at a speed estimated to be around 45 smph and showed little loss of speed ascending the 3% grade. The sound features worked admirably; no 120Hz hum noted.

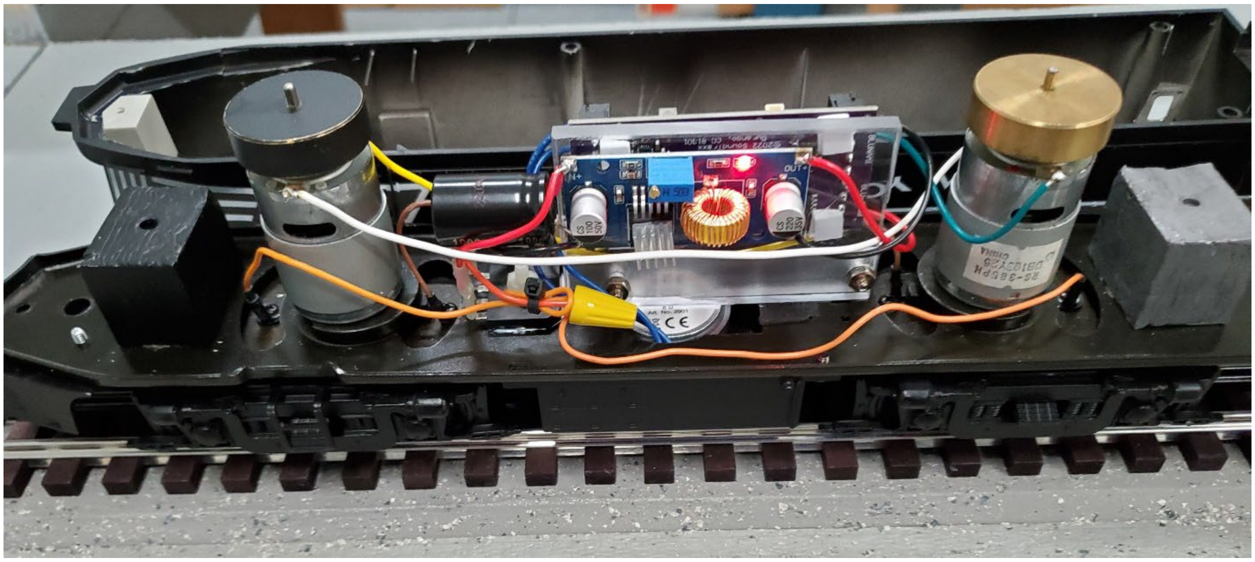
D. Final Configuration

The full-wave bridge rectifier was attached to the locomotive's base plate at the location where the QSI DCRU had been attached, using nylon hardware and heat sink grease. A vertical strip of 3/16" acrylic was attached to the plate to serve as a mounting surface for the DC>DC converter/regulator and Blunami controller cards.



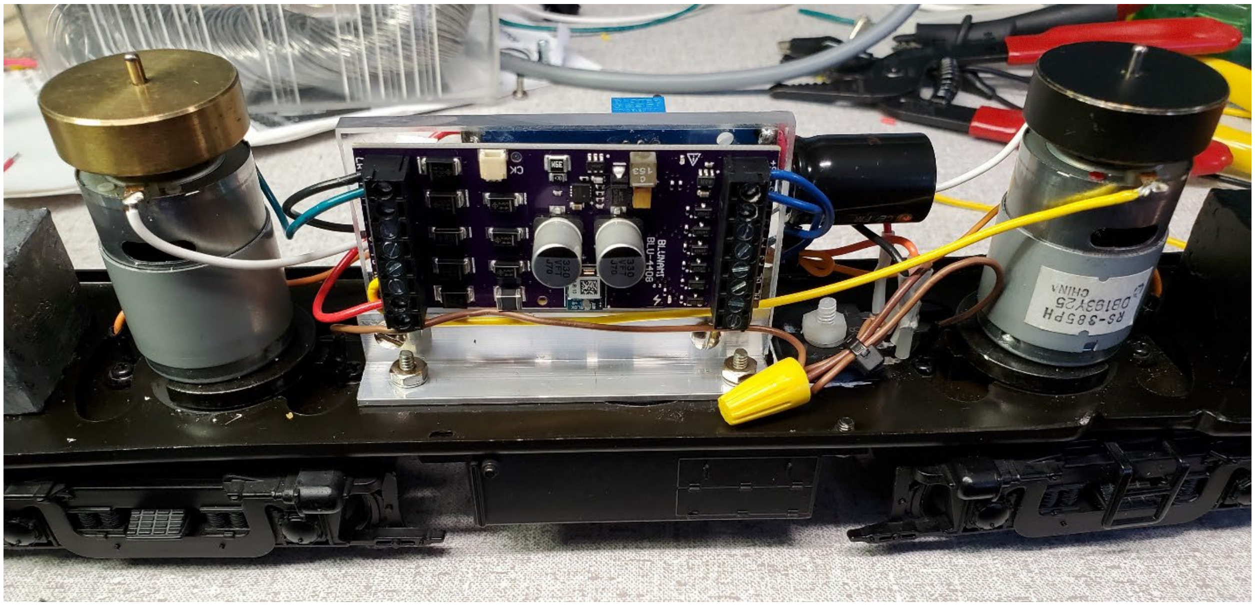
You can see the full-wave bridge rectifier attached to the base plate just to the right of the vertical acrylic piece, its leads covered with clear heat-shrink tubing.

The next picture shows the placement of the DC>DC buck converter/regulator, on the lef side of the support plastic. The FWB rectifier is attached to the frame on the left side of the regulator, with the 1000µF filter/smoothing capacitor attached directly to the input terminals of the regulator card, at its left side.



Were another Sharknose conversion to be done, the plastic support piece would be lengthened so that the electrocoupler interface (described later herein) card could be mounted on its right side, with both regulator and interface fitting between the motors easily.

The Blunami controller card, was located on the opposite side of the acrylic piece. The filter/smoothing capacitor is visible near the upper right side of the Blunami card, while the FWB bridge rectifier can be seen below it.

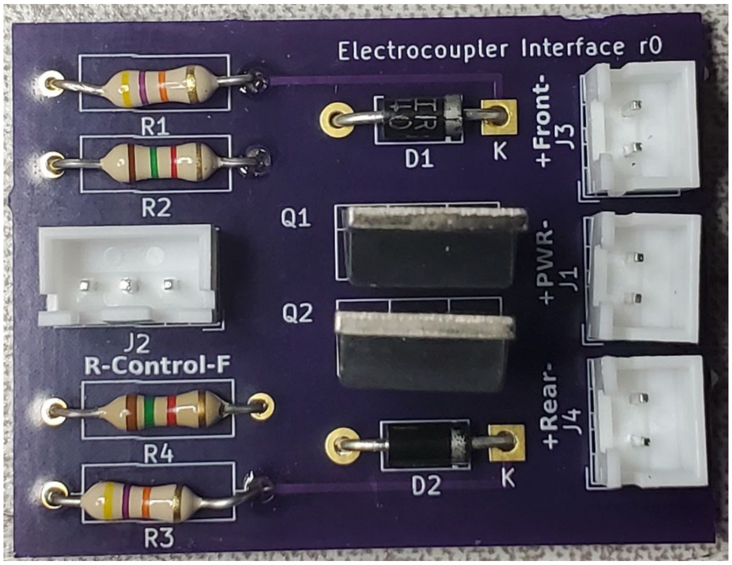


The grain-of-wheat headlight was replaced by a 3V white LED, using a 1200 Ohm current-limiting resistor to set the LED to around 11 mA. Another LED was mounted in the cup molded into the rear of the locomotive carbody, as a backup light.

Marker LEDs were installed at the nose of the locomotive. The 2mm LEDs used are green/red, with a common anode and two cathodes, one for each color. The green cathodes of the LEDs were connected in parallel with the headlight.

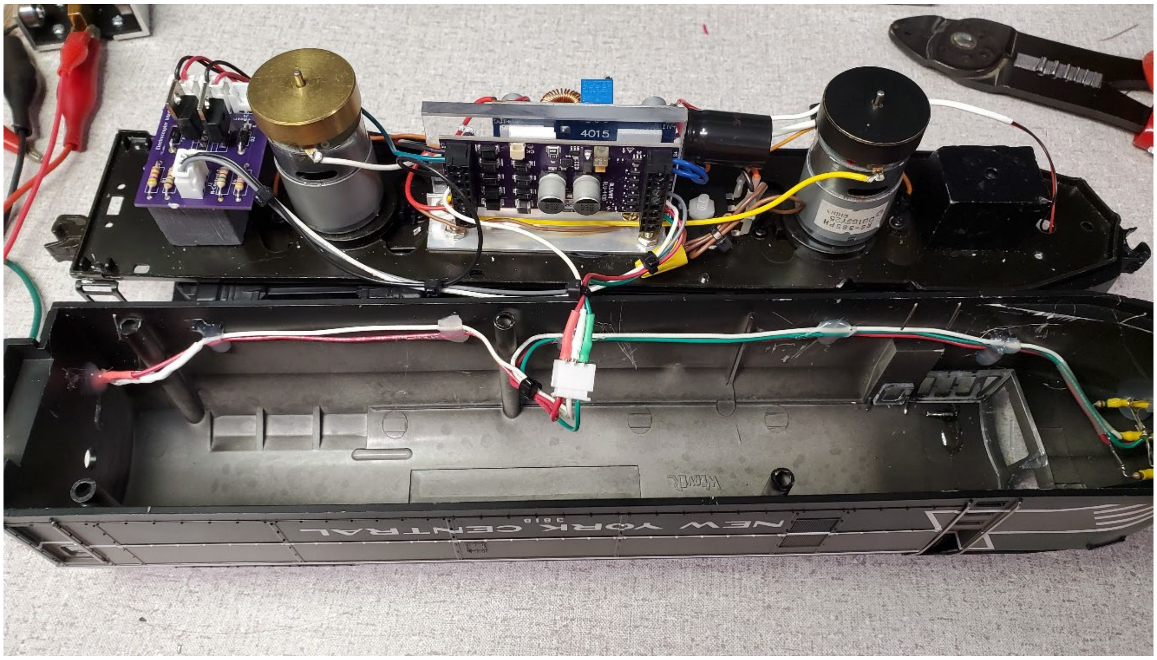
The red LED cathodes were connected in parallel with the backup light.

Electrocouplers draw around 1½-2A when opening, which exceeds the rating of the Blunami card's function outputs. A custom current booster circuit, using a single transistor, was designed to handle the electrocoupler current while drawing only a few milliamps from the Blunami FX3&4 outputs. The circuit board shown on the next page handles front and rear electrocouplers.



The component layout was tightened up to result in a somewhat smaller PC board in the second iteration of this interface, but there was no change in the circuit. The particular PNP power transistors used were chosen because plenty of them were already on hand.

The electrocoupler interface had not been conceived of when the mounting arrangements for the Blunami card and DC>DC converter/regulator were fitted. While its circuit card could easily have been placed between the motors with the other two PCBs, that would necessitate some rearranging, etc. that wasn't done. Instead, it was mounted atop the rear weight block, as shown below.



The converted Weaver Baldwin Sharknose has performed reliably, moving a 15-car freight train at around 50 smph and up 3% grades with ease, with 18VDC supplied to the Blunami card's DC input. As I become more familiar with the Blunami features, I expect that operation will continue to be refined.

Appendix V

The Blu Geep Project

MTH produced its 20-2033-x model of the New York Central dual-service GP-9 diesel in the 1990s. This release was painted in the NYC passenger two-tone gray scheme, while subsequent MTH versions were of the more numerous freight variant, painted black. It was equipped with PS=1 sound, but was conventionally controlled. The prototype units hauled branch-line trains throughout the NYC lines.

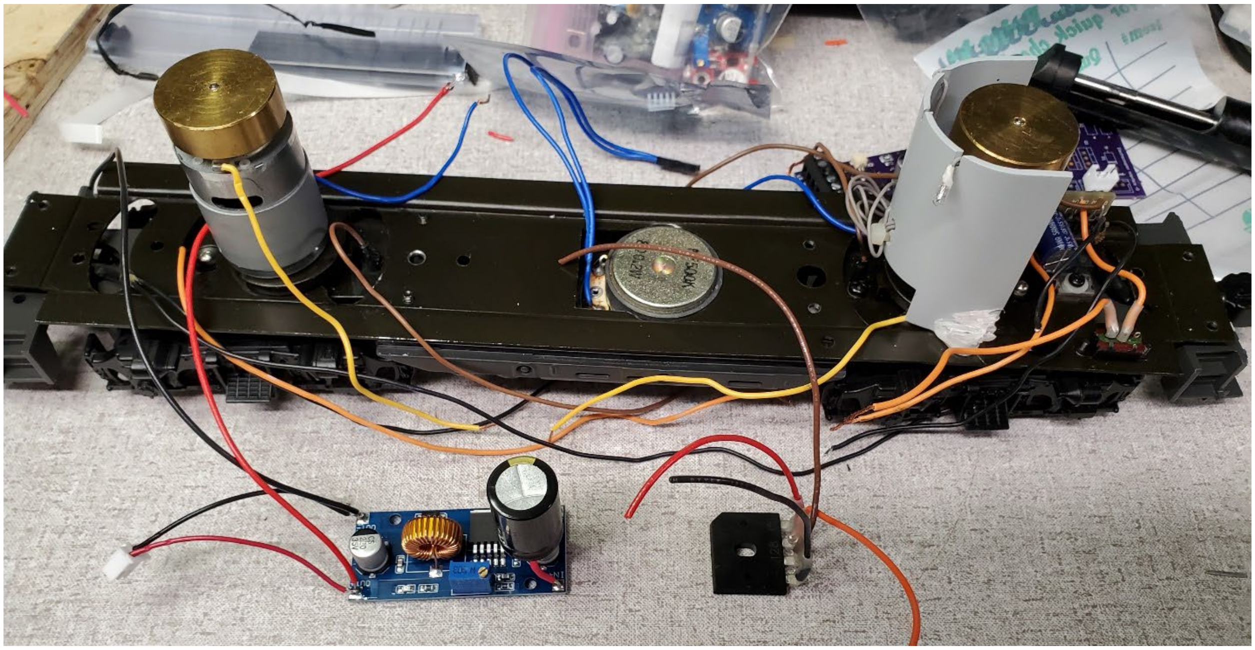
This became my second Blunami conversion project. Because this engine was used in passenger service, it needed to achieve higher speeds than one might accept for a freight engine. That made it a good candidate to evaluate the practicalities of dual-can-motor wiring for passenger engines.

A. Components

1. Full-Wave Bridge Rectifier: A Diodes, Inc. GBU-1001 bridge, with a peak inverse voltage rating of 100V and 10A continuous current rating, was chosen for this project.
2. Filter/Smoothing Capacitor: A Panasonic 1000µF, 50V radial lead electrolytic capacitor was used. While a smaller capacitor was feasible, part of this project included testing the locomotive without a DC>DC converter/rectifier, which necessitated a larger capacitor to keep voltage minima above 18V.
3. DC>DC Converter/Regulator: A Chinese "buck" downconverter, based on the XL4015 IC and rated at 5A, was obtained from envistiamall.com and installed in the model.

B. The Nude Geep

The following picture shows the MTH diesel with the original electronics removed, prior to installation of the AC>DC converter and Blunami controller card. The speaker remains in the fuel tank space.



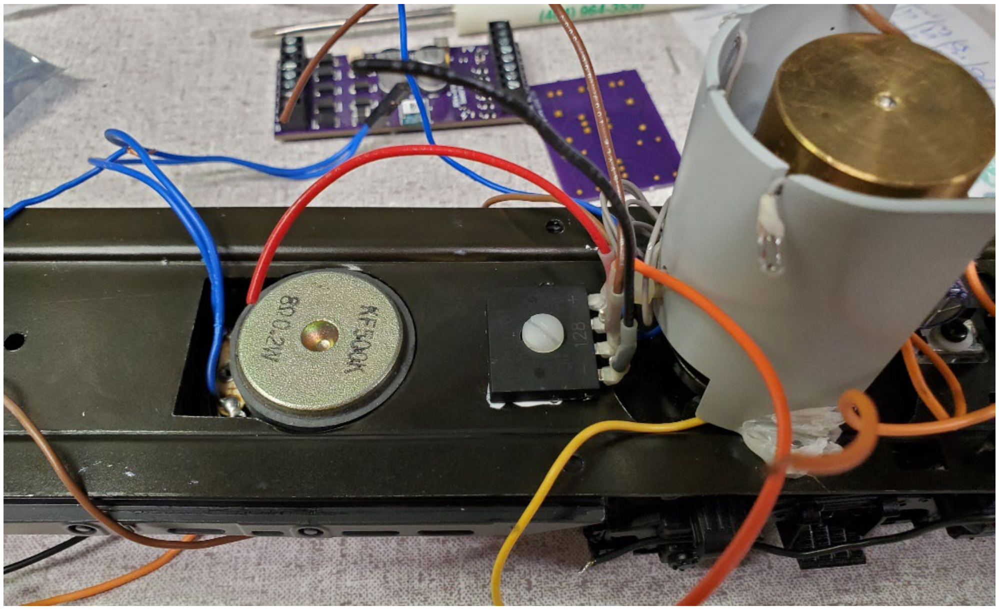
At the bottom of the picture, the DC>DC converter/regulator and FWB rectifier are shown, with their leads pre-wired.

C. Circuitry Placement

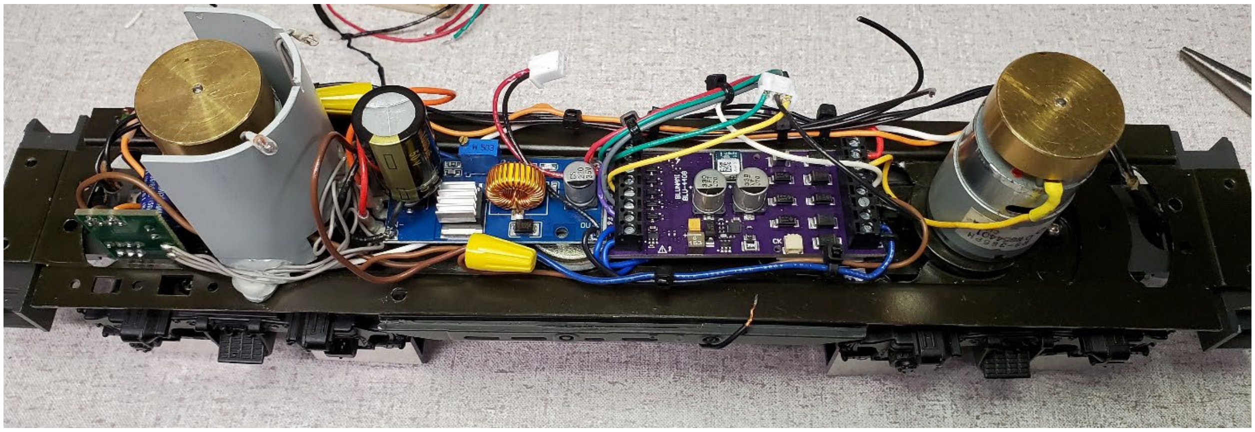
The narrow hood of the GP-9 introduced space utilization challenges not present in cab units. The hood width is not much more than an inch, while inside height clearance between the hood roof and base plate is $2^1/_8$”. The center rail pickup wires come through the locomotive’s base plate just inside of the two can motors, restricting space on that plate. These restrictions made card placement a significant puzzle.

Ultimately, it was decided to “layer” components off the base plate, which was facilitated by the speaker extending slightly above that surface. The DC<DC converter/regulator and Blunami circuit cards were placed end-to-end between the motors, with the electrocoupler driver card placed atop the Blunami card.

The FWB rectifier was mounted in the hole that previously provided access to the volume control potentiometer, as shown in the following picture.

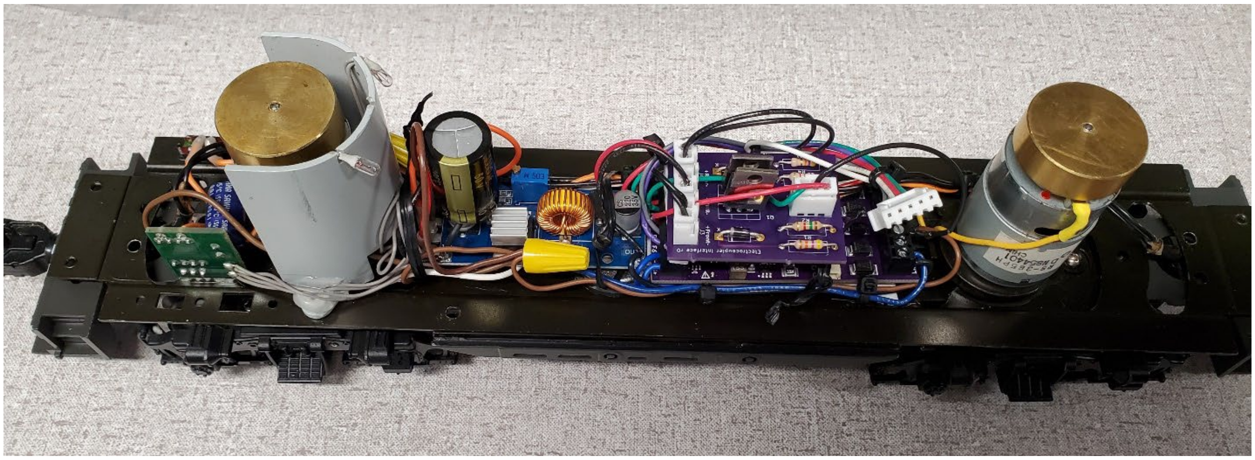


Its height was nearly that of the speaker, so the DC>DC converter/regulator card could be supported at one end by the speaker magnet and at the other end by the rectifier body. The next picture shows the next layer, the converter/regulator and Blunami cards, mounted, held in place by double-sided tape blocks on their bottom sides. The filter/smoothing capacitor was layered atop the input capacitor of the converter/regulator card and connected directly to its input, with the FWB rectifier output wires soldered to the capacitor leads.



To make this work, the cards were pre-wired before being mounted. Yes, the wiring is rather "busy" between those two can motors.

With no other location particularly practical and the desire to be able to remove the locomotive hood completely, the only practical location for the electrocoupler interface board appeared to be atop the Blunami card. One Blunami terminal block and the paired capacitors at the middle of the Blunami card were used to support the electrocoupler card, via double-sided tape that held the card in place. The next photo shows the "final" placement and wiring. The 5-pin JST plug located near the right-hand motor is the connector for the lighting mounted in the hood shell.



D. Reversing the Engineer

The NYC ran these locomotives long hood forward, at least during the 1950s, but MTH placed the cab engineer figure facing the short hood. He was glued in place by hot glue that could readily be cut out, so relocation to the opposite side of the cab, looking forward toward the long hood, was easy.

E. Lighting

The original MTH regulator card and wiring was retained for the cab lights. However, the headlight grain-of-wheat bulbs were replaced by high-intensity white LEDs. Dual-color marker LEDs were added next to the number boards at both ends. The wiring for these features was brought to a 5-pin JST connector near the Blunami controller card, so that the hood could be completely separated from the chassis if desired. Only 3 of the pins were used; the others were wired to unused Blunami function outputs for future use.

Here's the locomotive running forward:

And here it's reversed, with red markers forward:

F. Motor Wiring and Performance

Because this locomotive needed to achieve passenger train speeds, the output voltage of the DC>DC converter/regulator would need to be set higher than 18V, if the motors were connected in series. After assembly, the converter/regulator was set for 19VDC output. Surprisingly, the locomotive was able to pull 7 scale-length Golden Gate Depot heavyweight passenger cars (2-60', 1-70', 4-80') at 80 smph with the BluRail throttle set to 80%. Since series wiring of the motors respects the Blunami 4408 card's stall current limit of 4A and the desired speed could be obtained, the series connection was retained for this conversion.