

User's Manual for the ProMini Air Transmitter and Receiver

OScaleDeadRail
<https://oscaledeadrail.com>

Darrell Lamm
darrelllamm0@gmail.com

June 19, 2022
Copyright© 2019-2022, Darrell Lamm. All rights reserved.

Contents

1	Introduction	4
2	About DCC	4
3	Quick-Start	5
3.1	Additional Technical Information	7
3.2	Antennas for the ProMini Air	7
4	ProMini Air Settings/Configuration	10
5	Integration	14
5.1	Overview of Connections	14
5.2	Receiver Connections	18
5.3	Integration of the ProMini Air Receiver into a Locomotive	21
6	RF Receiver Compatibility	21
6.1	Airwire CONVRTR Series	21
6.2	QSI Solutions Gwire	26
6.3	Tam Valley Depot DRS1, MkIII	27
6.4	Tam Valley Depot DRS1, MkIV	27
6.5	NCE D13DRJ Wireless Decoder	28
6.6	Stanton S-Cab Receivers	28
6.6.1	Operating the S-Cab Throttle with the PMA Rx	29
6.7	OScaleDeadRail ProMini Air Receiver	33
6.8	Receiver and Decoder Behavior with Loss of RF	34
6.8.1	Airwire CONVRTR Series	36
6.8.2	Stanton Cab LXR-DCC Receiver	36
6.8.3	NCE D13DRJ	36
6.8.4	QSI Solutions Gwire and Tam Valley Depot DRS1 Series	36
6.8.5	OScaleDeadRail ProMini Air Receiver	36
A	Firmware Installation	40
	References	43
	Abbreviations/Acronyms	43
	Glossary	43

List of Figures

1	Typical model railroad battery-powered radio-controlled application	4
---	---	---

2	The components and connections needed for the ProMini Air transmitter . .	5
3	Example ProMini Air transmitter connections	6
4	The components and connections needed for the ProMini Air receiver . . .	7
5	Example ProMini Air receiver connections	8
6	LCD display showing DCC message sent	9
7	LCD display showing DCC message received	9
8	ProMini Air with an Liquid Crystal Display (LCD) display and DCC Con- verter/+5V Power Supply	13
9	Data and power connectionsfor PMA Rx	15
10	Data and power connections for PMA Tx	16
11	ProMini Air antenna connector (U.FL) and transceiver DCC input/output .	17
12	ProMini Air connections for AVR programmer, I2C display output, and 5V logic DCC input or output	17
13	ProMini Air power connection options (for Rx only, the Tx receives power from the DCC Converter)	18
14	ProMini Air receiver powered by an external +5V power supply (older PMA version, but the connections are the same for newer versions)	19
15	Close-up of ProMini Air receiver power connections to an external +5V power supply (older PMA version, but the connections are the same for newer versions)	20
16	Close-up of the inputs to the DCC amplifier from the ProMini Air receiver .	22
17	Example of another DCC amplifier's connections to the ProMini Air receiver	23
18	ProMini Air receiver integration with battery power, DCC amplifier, and antenna (older PMA version, but the connections are the same for newer versions)	24
19	Example Installation	24
20	Gwire U.FL connector	26
21	Tam Valley Depot DRS1, MKIII	27
22	The recently-released Tam Valley Depot DRS1, MkIV receiver	28
23	The recently-released Tam Valley Depot DRS1, MkIV receiver with U.FL plug	29
24	The NCE D13DRJ wireless decoder	30
25	The S-Cab LXR-DCC receiver with a built-in antenna.	31
26	Demonstration that the ProMini Air transmitter (yellow waveform) suc- cessfully transmits to the LXR-DCC receiver (blue waveform) on Channel 17. Note the very slight time delay of the LXR-DCC's waveform.	32
27	The ProMini Air receiver with a U.FL antenna.	33
28	ProMini Air's outputs with valid RF DCC signal	37
29	ProMini Air's DCC "Idle" outputs with no valid RF DCC signal, filtering off	38
30	Tam Valley Depot outputs with no valid RF DCC signal	38
31	ProMini Air's outputs with no valid RF DCC signal, filtering on	39
32	GitHub Source download	40

List of Tables

1	ProMini Air Settings and Configuration	12
2	RF Receiver Summary	25

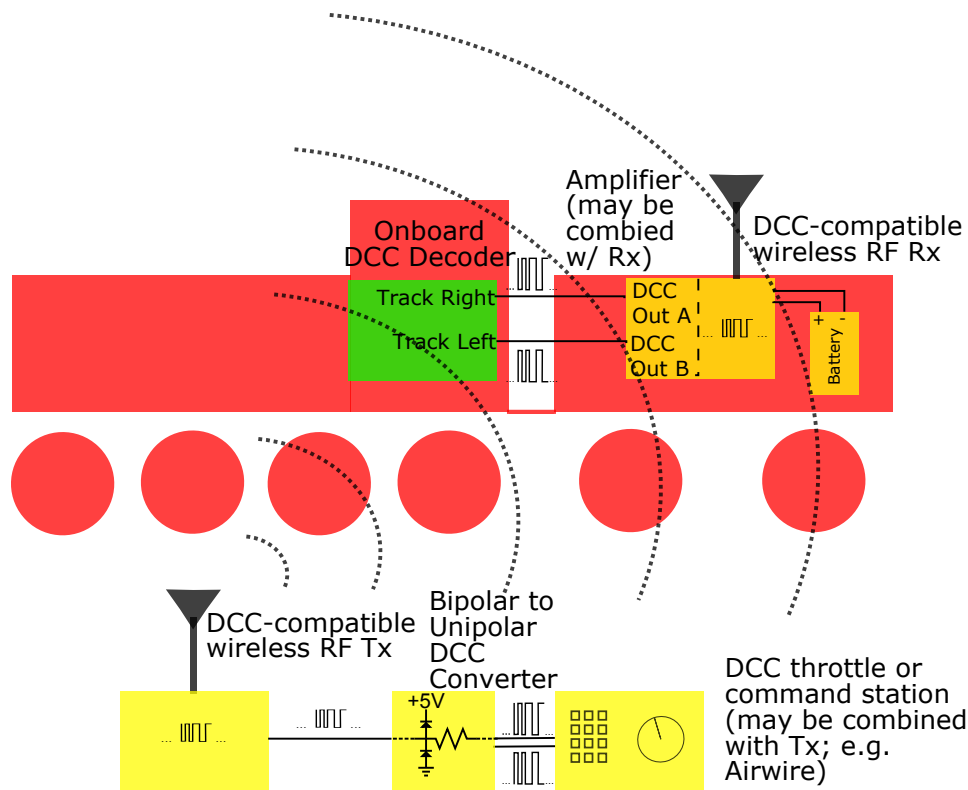


Figure 1: Typical model railroad battery-powered radio-controlled application. In some cases, such as the Airwire transmitters, the throttle and transmitter are combined. Also, the receiver and amplifier may be combined, such as for Airwire and Tam Valley Depot receivers. We provide the required DCC Converter for the PMA Tx or DCC Amplifier for the PMA Rx.

1 Introduction

Before understanding how to set up and use the ProMini Air transmitter and receiver, let's set the stage with Figure 1. What's different from typical model railroads is that power comes from a battery rather than electrified rails, and DCC (more about this in a moment) control information is received by a radio receiver (from a radio transmitter connected to a DCC throttle) rather than from DCC signals imposed on the track voltage by a throttle. This battery-powered, radio-controlled method of operation is sometimes called “dead-rail” because neither power nor signal is applied to the rails.

2 About DCC

We'll introduce some terminology that may be new. The National Model Railroad Association (NMRA) set forth a standard [1] for communicating with decoders onboard locomotives and other model railroad devices called Digital Command Control (DCC). DCC-compliant throttles control and configure these devices by sending coded, digital voltage

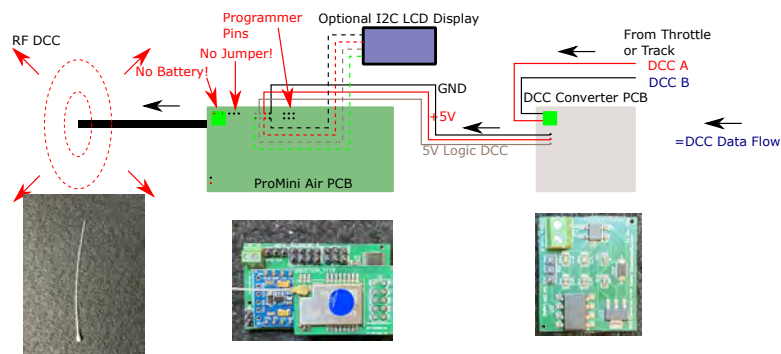


Figure 2: The components and connections needed for the ProMini Air transmitter

waveforms over wires or tracks (usually) to these devices, which sift out those addressed to them. These coded waveforms contain digital messages or “packets” specify an action and an “Address” that determines the recipient device. Most DCC packets are addressed to a specific recipient, although a few kinds of messages are for *all* listening recipients.

Any DCC output (say from Digitrax, NCE, or other DCC throttle) can be wirelessly transmitted using the ProMini Air transmitter over the Airwire Frequencies in the North American 902–928 MHz or European 868-870 MHz “ISM Band” band (the Airwire or European channel and output power level is adjustable as described below) to a variety of RF receivers, including the ProMini Air receiver, that in turn convert the RF transmissions back to DCC signals any DCC decoder can “understand.”

After the ProMini Air has been interfaced and powered as described in the next section, the ProMini Air transmitter or receiver can be operated without further ado. However, you can reconfigure some aspects of the ProMini Air’s operation as described later in this Manual.

3 Quick-Start

We provide the ProMini Air as a fully-assembled, modular device, already connected to the additional components necessary to act as either a transmitter or receiver. For the ProMini Air transmitter, you simply connect the DCC Converter to a DCC throttle’s Track R/L output that is used as both a power and DCC data source (Figures 2 and 3). For the ProMini Air receiver, connect battery power to the power harness plug and plug the DCC amplifier’s output to the Track R/L inputs to DCC decoder (Figure 4 and 5).

Both the ProMini Air transmitter and receiver can be optionally connected to an LCD display that uses the “I2C” interface that has GND, VCC (+5V), SDA (data), and SCL (clock) inputs. The display provides information on DCC messages received (PMA < DCC.Packet) and sent (PMA > DCC.Packet). See Figures 6 and 7.

Of course the LCD display cannot be used once the ProMini Air receiver is mounted,

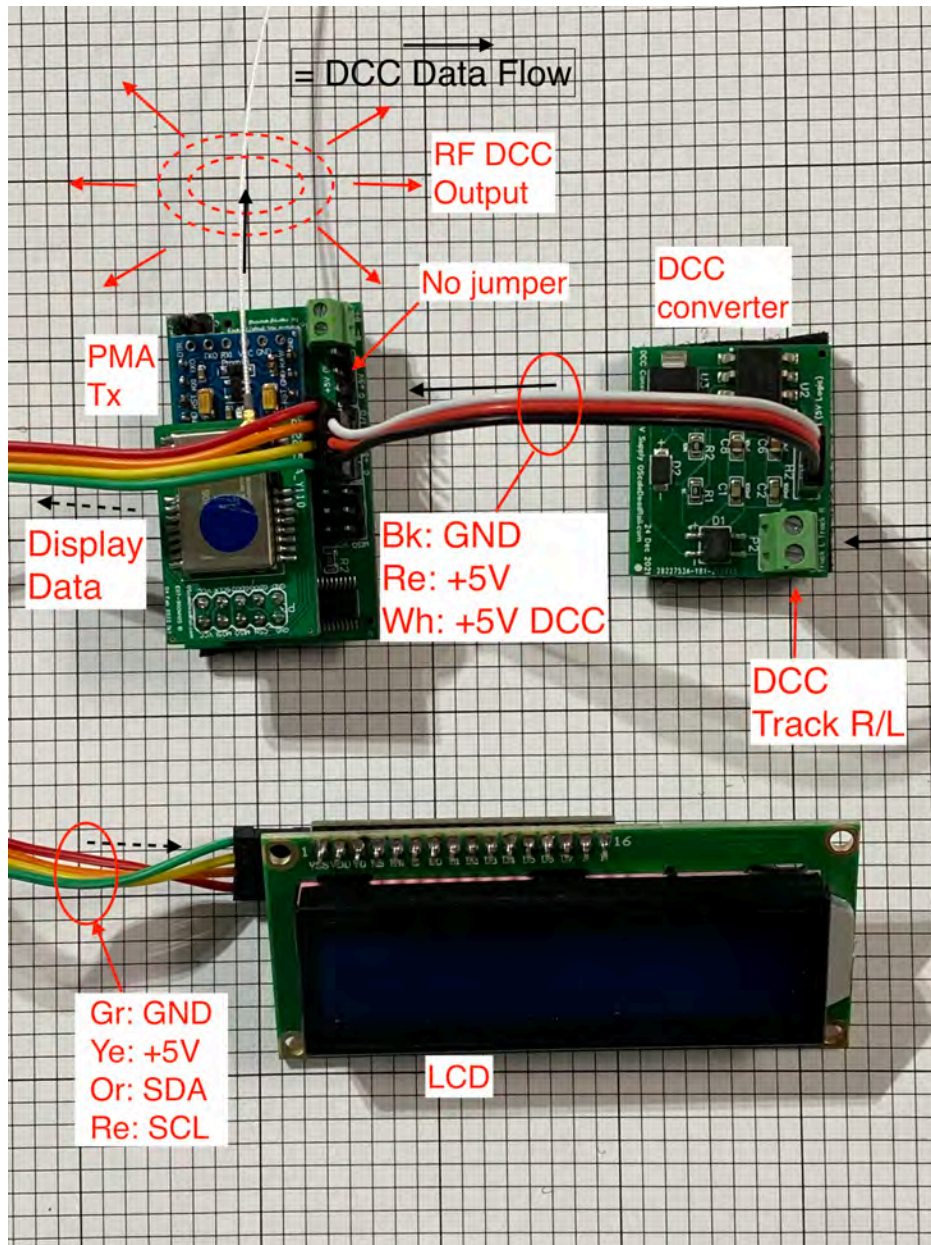


Figure 3: Example ProMini Air transmitter connections

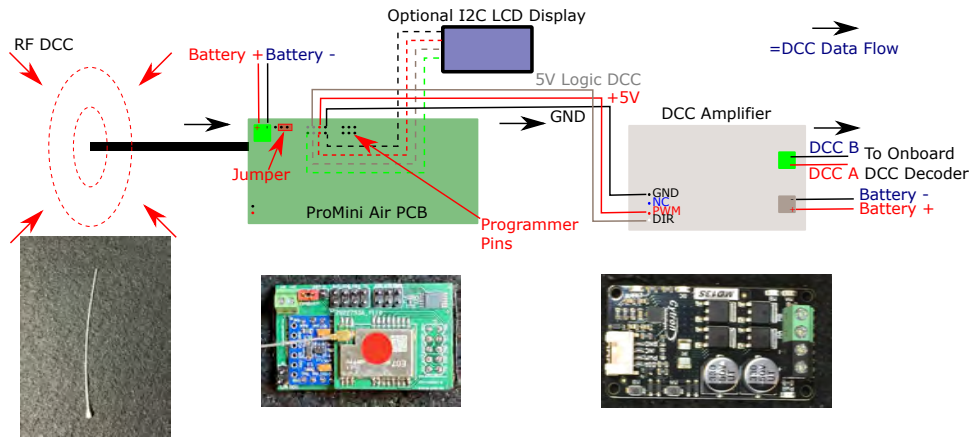


Figure 4: The components and connections needed for the ProMini Air receiver

but we strongly suggest that you keep the LCD display connected to the ProMini Air transmitter so that you can monitor changes in the ProMini Air transmitter’s settings such as broadcast channel and power.

3.1 Additional Technical Information

The ProMini Air requires interfacing to additional electronics that are provided. For the transmitter, the DCC signals that would normally be applied to the tracks by a DCC throttle are input to a simple “DCC Converter” that provides both 5V DC power and 5V logic DCC signal for the ProMini Air transmitter. See Figure 2 and 3.

For the receiver, the 5V logic DCC signal output by the ProMini Air receiver is converted by a “DCC amplifier” back to “track DCC” signals that an onboard DCC decoder can “understand.” See Figure 4 and 5.

We decided to take this modular approach to allow: 1) the user to replace failed components (and not the entire assembly) and 2) us to reduce our exposure to supply chain disruptions and parts obsolescence, keeping costs low.

We believe this “modular” approach gives you flexibility for both installation and parts replacement. An additional benefit of the ProMini Air’s modularity is that a transmitter can be repurposed as a receiver or vice versa with a simple firmware change.

3.2 Antennas for the ProMini Air

The ProMini Air *transmitter* comes with a “whip” antenna that preserves FCC/IC/ETSI/CE approval for the ProMini Air *transmitter* containing the Anaren A110LR09x or A1101R09x or the Ebyte E07-900M10S transceiver daughterboards. The approval numbers are the following:

- FCC ID: X7J-A1107 (Anaren), 2ALPH-E07900M10S (Ebyte)
- IC: 8975A-A11072401

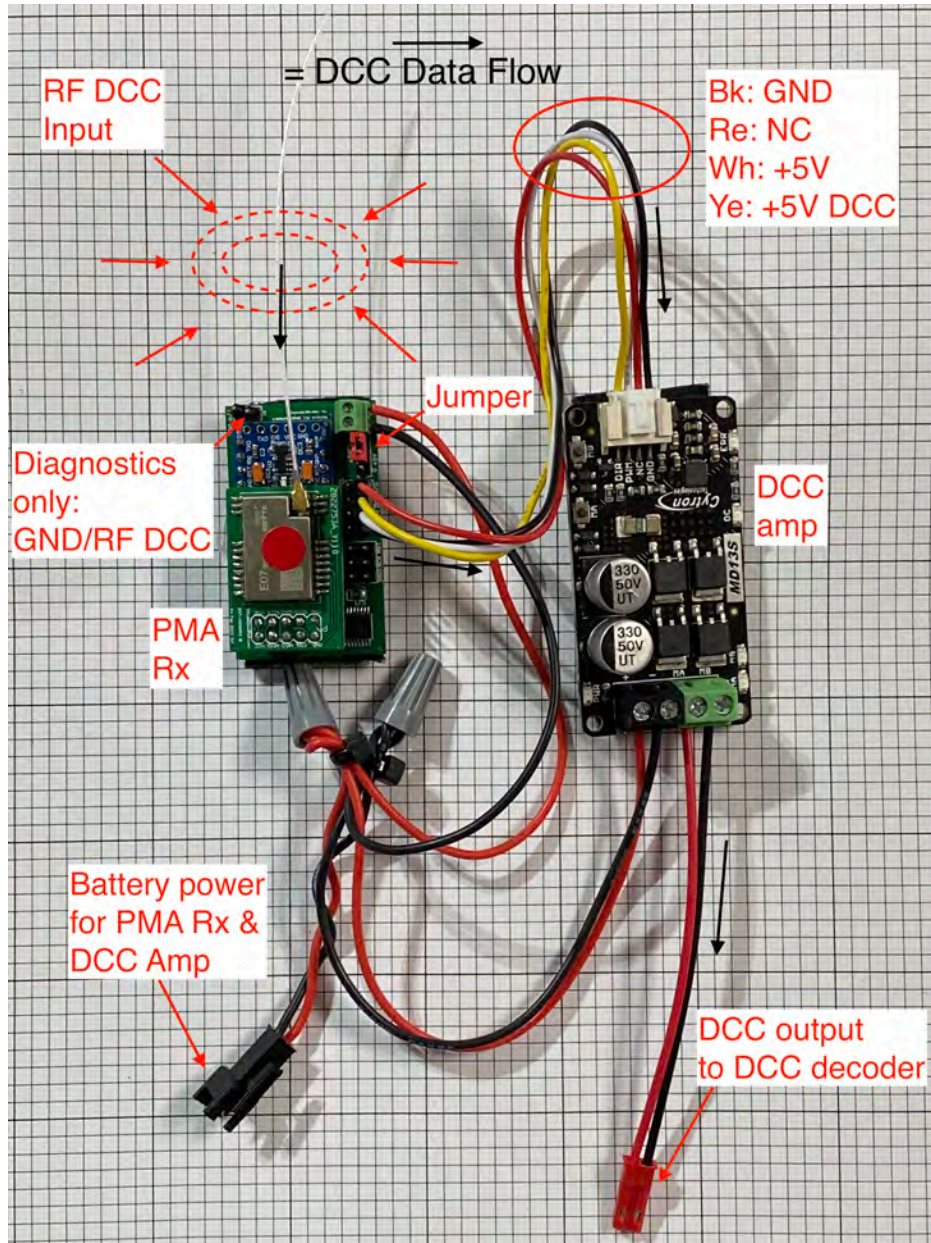


Figure 5: Example ProMini Air receiver connections



Figure 6: LCD display showing message DCC sent (Tx: sent wirelessly; Rx: sent to DCC amplifier)



Figure 7: LCD display showing message DCC received (Tx: received from DCC throttle; Rx: received wirelessly)

The following is a required FCC notice:

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

The following is a required IC notice:

Notice: This device complies with Industry Canada licence-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Avis: Cet appareil est conforme avec Industrie Canada RSS standard exempts de licence (s). Son fonctionnement est soumis aux deux conditions suivantes: (1) cet appareil ne peut pas provoquer d'interférences et (2) cet appareil doit accepter toute interférence, y compris les interférences qui peuvent causer un mauvais fonctionnement du dispositif.

The [OScaleDeadRail site](#) discusses antennas that may be used with the ProMini Air *receiver* in cases where the provided whip antenna is not feasible to use. We do not recommend you replace the approved antenna for the ProMini Air *transmitter* because it may violate the FCC/IC/ETSI/CE approvals for an “active transmitter.”

4 ProMini Air Settings/Configuration

Note: The instructions here refer to both the ProMini Air transmitter (Tx) and receiver (Rx). Where necessary, we will try to differentiate between these options with “Tx” or “Rx” for the ProMini Air transmitter or receiver, respectively.

The ProMini Air has many default configuration settings that should make it useful “out of the box,” and “OPS Mode” (sometimes called “Programming on the Main” or “PoM”) re-configuration by the DCC throttle described below can change these settings, perhaps the most important of which is the Airwire Radio Frequency (RF) channel to transmit/receive on. But first, we need to explain how to make the ProMini Air “listen” to the DCC throttle’s re-configuration commands explicitly meant for the ProMini Air.

While DCC throttles are mostly concerned with commanding the speed, direction, and other behavior of locomotives, they can be used to reconfigure the “decoders” that are busy interpreting the DCC commands sent by the DCC throttle. Usually, reconfiguration involves changing lighting effects and other behavior of devices on a locomotive *at a specific address*, and “OPS mode” is very convenient for doing so. Each DCC throttle manufacturer has a slightly different method for putting the throttle into “OPS mode” so that it can communicate with a decoder at a specific address, but once in this mode, the DCC throttles all send the same NMRA-compliant, DCC packets to reconfigure the recipient decoder by means of changing the *value* of a *Configuration Variable* (CV).

This last point is the source of a lot of confusion. A *Configuration Variable* (CV) is the *fixed address number with a set purpose* where we will deliver a *change in its value held at this address*. We usually refer to the *fixed address with a set purpose* as “CV#”, where # is some number. For instance, CV1 holds the value of a device’s “short address” (whose *value* can be between 1 and 127). The *value* stored at this address can be changed, so we often refer to the *value* held at the CV address # as “CV#=value.”

The ProMini Air “listens” to electrical signal DCC commands from the throttle (Tx) or from a wireless DCC signal (Rx), and if the address of a command matches the ProMini Air’s address, which is 9900(Tx)/9901(Rx) by default (CV17=230, CV18=172(Tx)/173(Rx)), while the throttle is in “OPS mode”, the ProMini Air can be re-configured. *Note: Previous versions of ProMini Air had default long addresses of 9000(Tx)/9001(Rx) (CV17=227, CV18=40(Tx)/41(Rx))!*

Table 1 provides CVs that can be changed to re-configure the ProMini Air. To change these values, the throttle that the ProMini Air connects (Tx) or RF DCC signal listens (Rx) to must first select the current address of the ProMini Air, which is 9900(Tx)/9901(Rx) by default. Then according to the instructions for the particular throttle, set the throttle in “OPS mode” or “programming-on-the-main” of Configuration Variables (CVs).

Table 1 also provides valid values for the CVs, so if the user attempts to set an invalid value for a CV, the entry will be ignored and will NOT take effect! All changes to CV values made in “OPS mode” are persistent after power-down except for CV254 (RF power level), which will reset to the original default value of 8 upon power-up. This setting has no important effect on the ProMini Air receiver (Rx). This feature prevents the ProMini Air transmitter from producing unexpected high-power RF output upon turn-on.

In general, it should not be necessary to change the ProMini Air’s address. But, if the user needs to change the address, the following information will help. It’s a little complicated. If the user is not changing from a short to a long address or vice versa, no change in CV29 is needed. The fifth bit of CV29 specifies whether to use a “long” (bit 5=1) or “short” (bit 5=0) address. For the ProMini Air, no other bits of CV29 are relevant, so either set CV29=0 to use the “short” address specified in CV1 or set CV29=32 to use the “long” address specified by CV17 and CV18.

When resetting the “long address” for the ProMini Air, the user *must* set CV17 *before* setting CV18! Once the user programs the value of CV18, the ProMini Air’s address will change to the new address, whose value is set by the funny formula:

$$\text{Address} = (\text{CV17value} - 192) * 256 + \text{CV18value},$$

so for the default values for CV17 and CV18 in Table 1: $(231-192)*256 + 15/14(\text{Tx/Rx})$

Table 1: ProMini Air Settings and Configuration

Feature	CVAddress	Valid CV Values	Default	Comments
RF Channel	CV255	0–16, 17, 18	0	Airwire Ch. 0-16, S-Cab Ch. 17, EU Ch. 18
RF Power*	CV254	0–10	8	Experimentation is required
Transceiver On/Off	CV253	0 or $\neq 0$	0	Transceiver sleep when bad DCC packets present
DCC sampling time	CV252	0–255	4	Time in 1/4 s intervals for DCC sampling before turn-off
Transceiver sleep time	CV251	0–255	0	Time in 1/4 s intervals for transceiver sleep
Bad transition counts, low btye	CV250	0–255	100	Low byte of maximum bad DCC transitions
Bad transition counts, high btye	CV249	0–255	0	High byte of maximum bad DCC transitions
DC Level	CV248	0 or $\neq 0$	1	DCC A level when no valid DCC and DCC filtering on
Idle time in ms	CV247	0–255	0	Wait time in ms before forcing DCC IDLE packet send if more than 2 DCC packet repeats
DCC filtering	CV246	0 or $\neq 0$	0	DCC filtering OFF (= 0) or ON ($\neq 0$) (Rx)
Channel wait period	CV245	0–60	1	Channel waiting period in sec (Rx)
Automatic IDLE Insertion off	CV244	0 or $\neq 0$	0	Turn OFF (= 1) or ON ($\neq 0$) automatic IDLE packet insertion (Tx)
Configuration	CV29	0–255	32	CV29=32 to use long address
Long addr low byte	CV18	0–255	15(Tx)/14(Rx)	Default CV17 & CV18 make Address = 9900(Tx)/9901(Rx)
Long addr high byte	CV17	192–231	231	Program CV17 <i>before</i> CV18!
Factory reset	CV8	8	NA	CV8=8 causes “factory” reset
Short addr	CV1	1–127	3	CV29=0 to use short address

*Resets to default on power-up

= 9900(Tx)/9901(Rx). Changing the address by first setting CV17 and then CV18 means that the ProMini Air will no longer accept “OPS mode” changes at the *old* address, and the user must change the throttle’s address to the *new* address before going back into “OPS mode” for any further configuration changes to the ProMini Air. Similarly, if the user changes the value of CV29, then the address for the ProMini Air may have changed from long-to-short or short-to-long address, so the user must change the address on the throttle to communicate with the ProMini Air in “OPS mode” at the *new* address.

It may become necessary to reset the ProMini Air completely. An example is when power “glitches corrupt the EEPROM memory” during start-up when the ProMini Air is writing to EEPROM. The user can force a “factory” reset where the ProMini Air is returned to its original settings by setting the throttle or wireless transmitter into “OPS” mode, selecting the ProMini Air’s DCC address, and setting CV8 to 8. The ProMini Air will ignore other values for CV8. If successfully executed, the ProMini Air will display a reset message if an LCD is connected. Regardless, *do not turn off the power during reset*, which may last

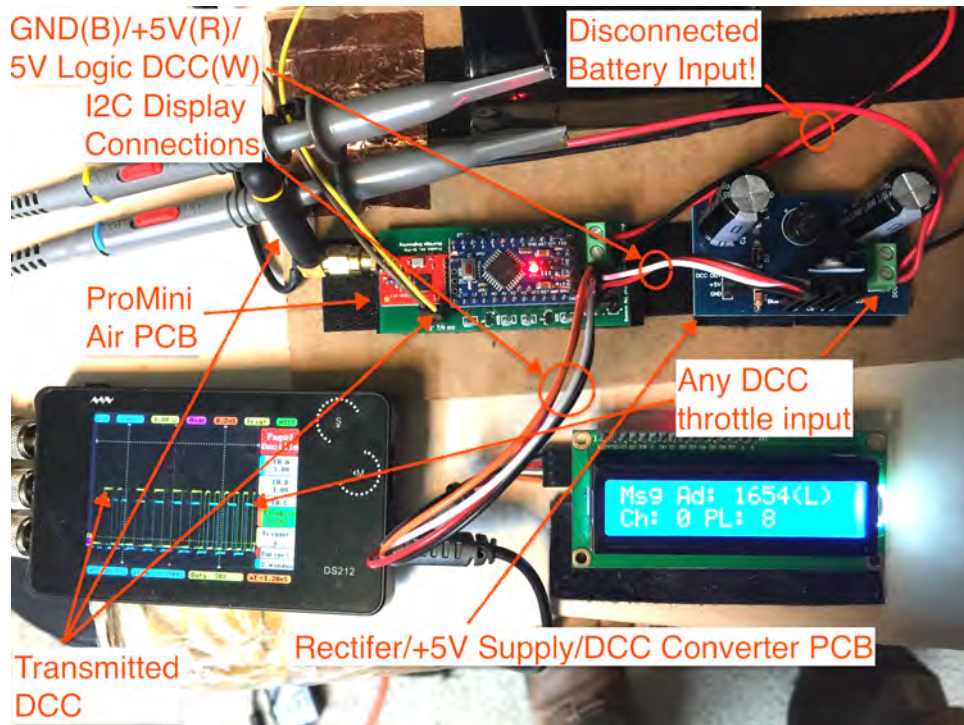


Figure 8: ProMini Air with an LCD display and DCC Converter/+5V Power Supply

several seconds. Turning off power during reset almost guarantees EEPROM corruption, requiring yet another “factory” reset, so please wait at least ten seconds before turning off the ProMini Air following a factory reset.

A small LCD display with an “I2C” interface can be attached to the ProMini Air via the 4-pin connector to provide the user with useful information. The I2C address of the LCD display is typically either 0x27 (39 decimal) or 0x3F (63 decimal). The ProMini Air will attempt to “find” the display by automatically searching a range of I2C addresses, so the user does not need to know the display’s address.

The LCD shown in Figure 8 displays the ProMini Air’s address, Airwire channel number, and power level. The display is a FICBOX IIC/I2C 1602 Serial 5V Blue Backlight LCD Display for Arduino 2560 UNO AVR (which can be purchased [here](#)). There are many of these kinds of displays available that use an “I2C” interface, and will probably work. The ProMini Air provides a 4-pin interface to “I2C” display: GND, +5V (VCC), SCA, and SCL. It is crucial to make a contrast adjustment of the LCD using a small screwdriver to adjust the contrast potentiometer on the back of the display. Many users believe the display is defective simply because the contrast setting is wrong. See Figure 8.

A *modified* Arduino [LiquidCrystal_I2C library](#) by Frank de Brabander is included at the GitHub [site](#) for the ProMini Air to implement the display functions. You *must* use the modified version of this library included at the ProMini Air’s GitHub site! We modified the library for global instantiation without parameters, and the `init` method uses parameters to initialize the display in a locally-scoped function.

Some final points about the reconfiguration of the ProMini Air:

- While many DCC throttles have alternative methods for re-configuring decoders, such as “Service Mode” and “Quick Decoder Setup”, the only method that the ProMini Air will respond to is the very simple “OPS Mode” or “programming-on-the-main mode” that allows specific CVs to be *directly* set.
- Technically the ProMini Air is not a “multi-function” decoder, but we have chosen the addressing and reconfiguration of the ProMini Air as if it were one because the user usually becomes quite adept at quickly:
 1. changing the decoder address to the ProMini Air’s,
 2. putting the throttle in “OPS mode”,
 3. making CV changes to re-configure the ProMini Air,
 4. exiting “OPS mode”, and finally
 5. changing the DCC throttle address back to whatever locomotive the user is trying to control.

5 Integration

To complete the integration of the ProMini Air receiver (Rx) or transmitter (Tx), you must establish several connections.

5.1 Overview of Connections

See Figures 9 and 10 for an overview of the connections to and from the ProMini Air. Which connections you use depends on whether the ProMini Air will act as a receiver (Rx) or a transmitter (Tx). **THERE IS NO PROTECTION AGAINST INCORRECT BATTERY OR EXTERNAL POWER CONNECTIONS!!!** You will destroy the ProMini Air **immediately** if you reverse the GROUND and POSITIVE POWER SUPPLY connection!

The Anaren and Ebyte transceiver daughterboards have a versatile U.FL plug for antenna connections. You can plug in either the Anaren whip antenna we provide or a U.FL-to-SMA or U.FL-to-RP-SMA cable that screws into a remotely-mounted antenna. Also, a two-pin output provides Ground and the DCC input to (Tx) or output from (Rx) the RF transceiver board, serving as signals to an oscilloscope for waveform review. See Figure 11 for details on these connections.

The ProMini Air has several connections that provide AVR programmer, I2C display outputs, and 5V logic DCC inputs or outputs. See Figure 12.

We will break down these connections for the ProMini Air receiver and transmitter in the following two sections.

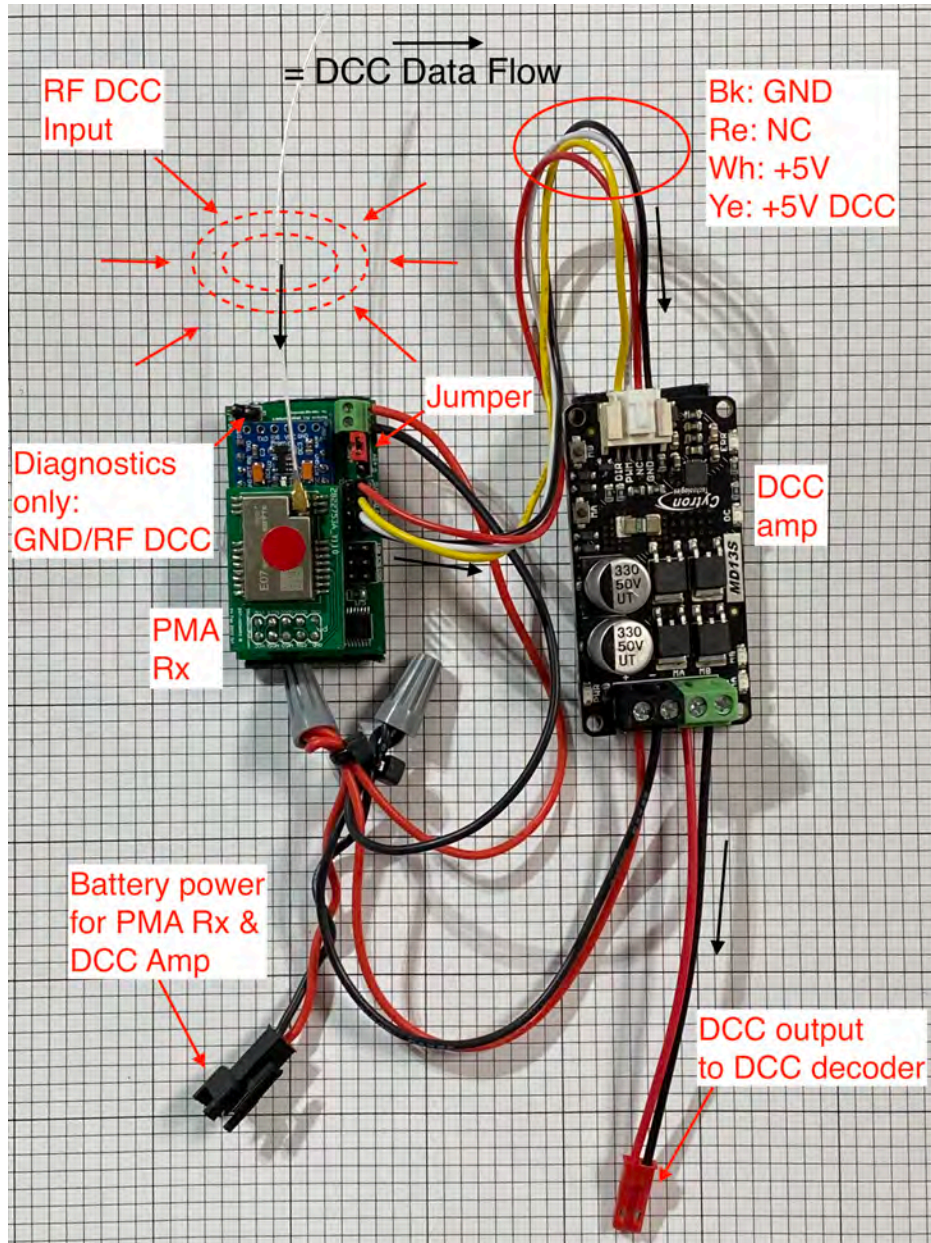


Figure 9: Data and power connections for PMA Rx

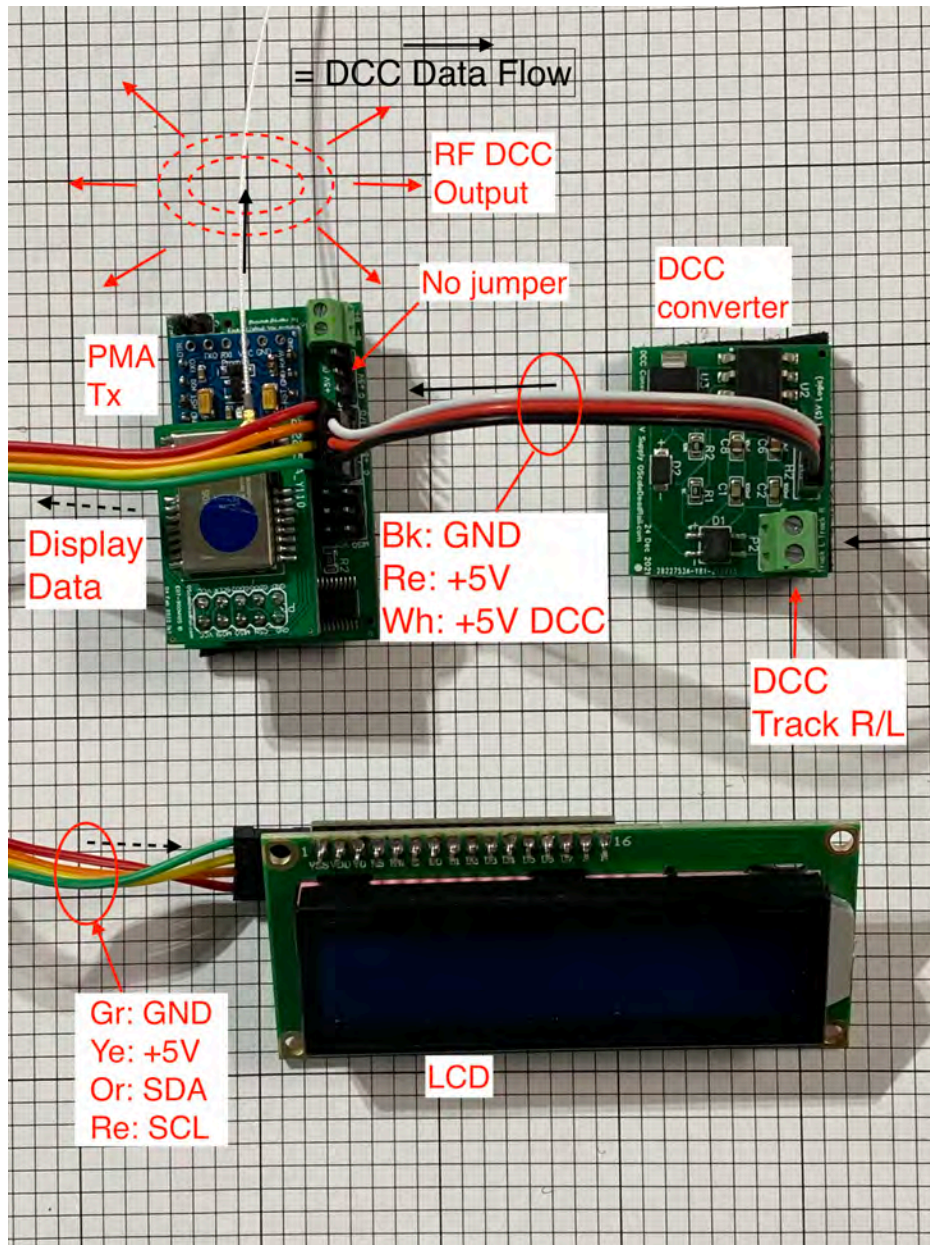


Figure 10: Data and power connections for PMA Tx

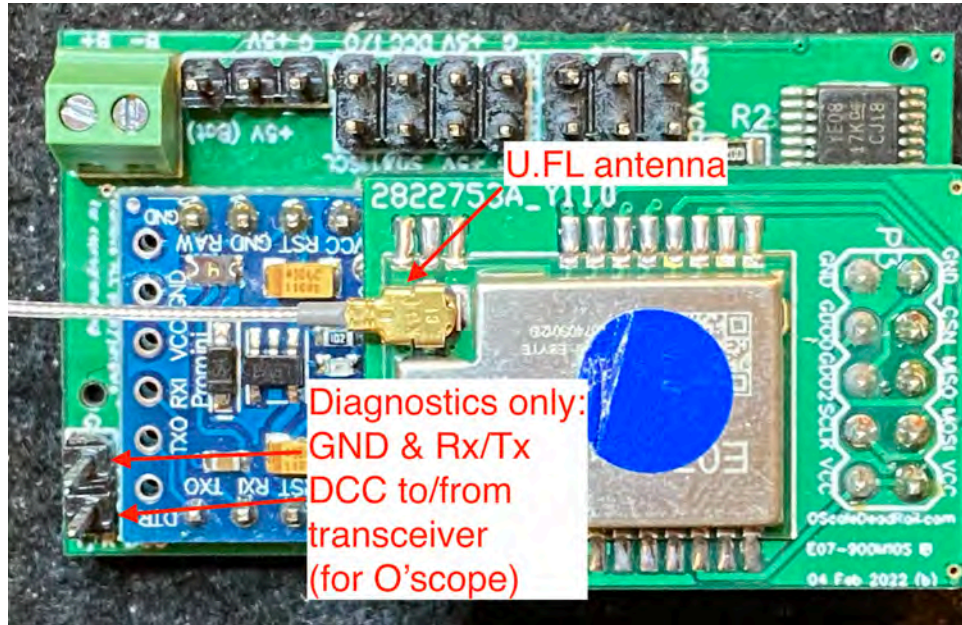


Figure 11: ProMini Air antenna connector (U.FL) and transceiver DCC input/output

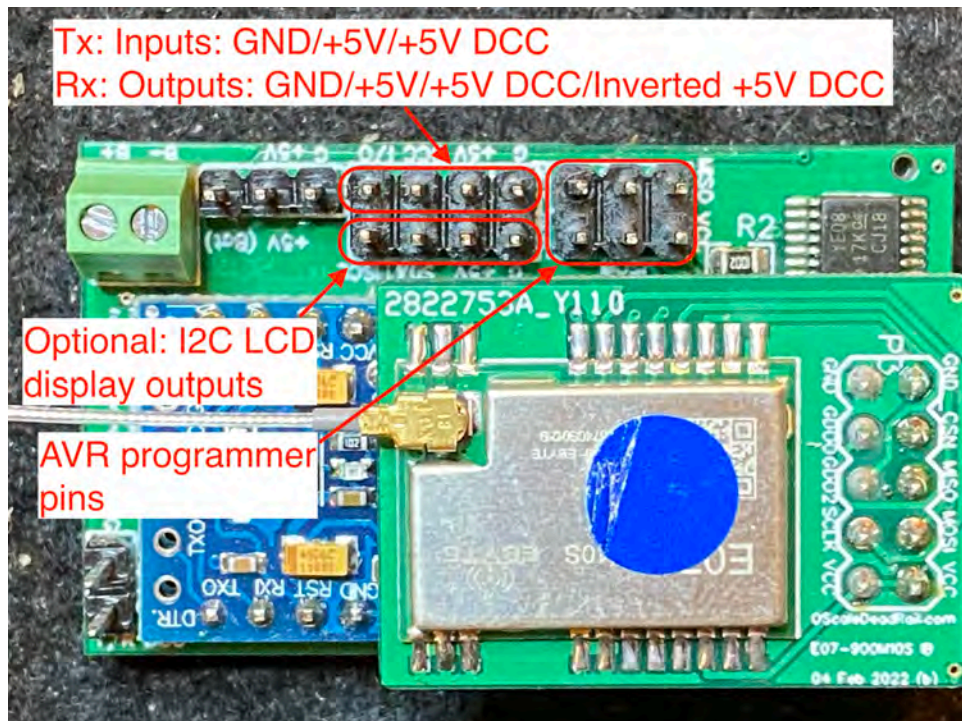


Figure 12: ProMini Air connections for AVR programmer, I2C display output, and 5V logic DCC input or output



Figure 13: ProMini Air power connection options (for Rx only, the Tx receives power from the DCC Converter)

5.2 Receiver Connections

Starting with the ProMini Air configured as a receiver (Rx), several options exist for providing power. The first option is to use external battery power and jumper the +5V and +5V (Battery) pins to use the onboard 5V regulator to provide board +5V supply. See Figure 13.

Since you may not like the heat generated by the onboard 5V regulator when you supply power with external battery power and install the jumper, as an alternative, you may use an external +5V power supply, as shown in Figures 14 and 15, where the external power supply provides Ground and +5V. Of course, you do NOT install the jumper.

The ProMini Air receiver must connect to an external DCC amplifier that converts the 5V logic DCC from the ProMini Air receiver to DCC A/B that a DCC decoder requires. This DCC amplifier uses battery power and the inputs from the ProMini Air receiver to provide the power and DCC messages, coded as a bipolar DCC waveform, to the decoder for both power and DCC messages.

These “DCC amplifiers” are usually medium to large amperage amplifiers that accept pulse width modulation (PWM) input to provide precision output control for electric motors. The maximum PWM frequency of these amplifiers is usually high enough ($> 20\text{kHz}$) to reproduce DCC packets accurately. See Figure 16.

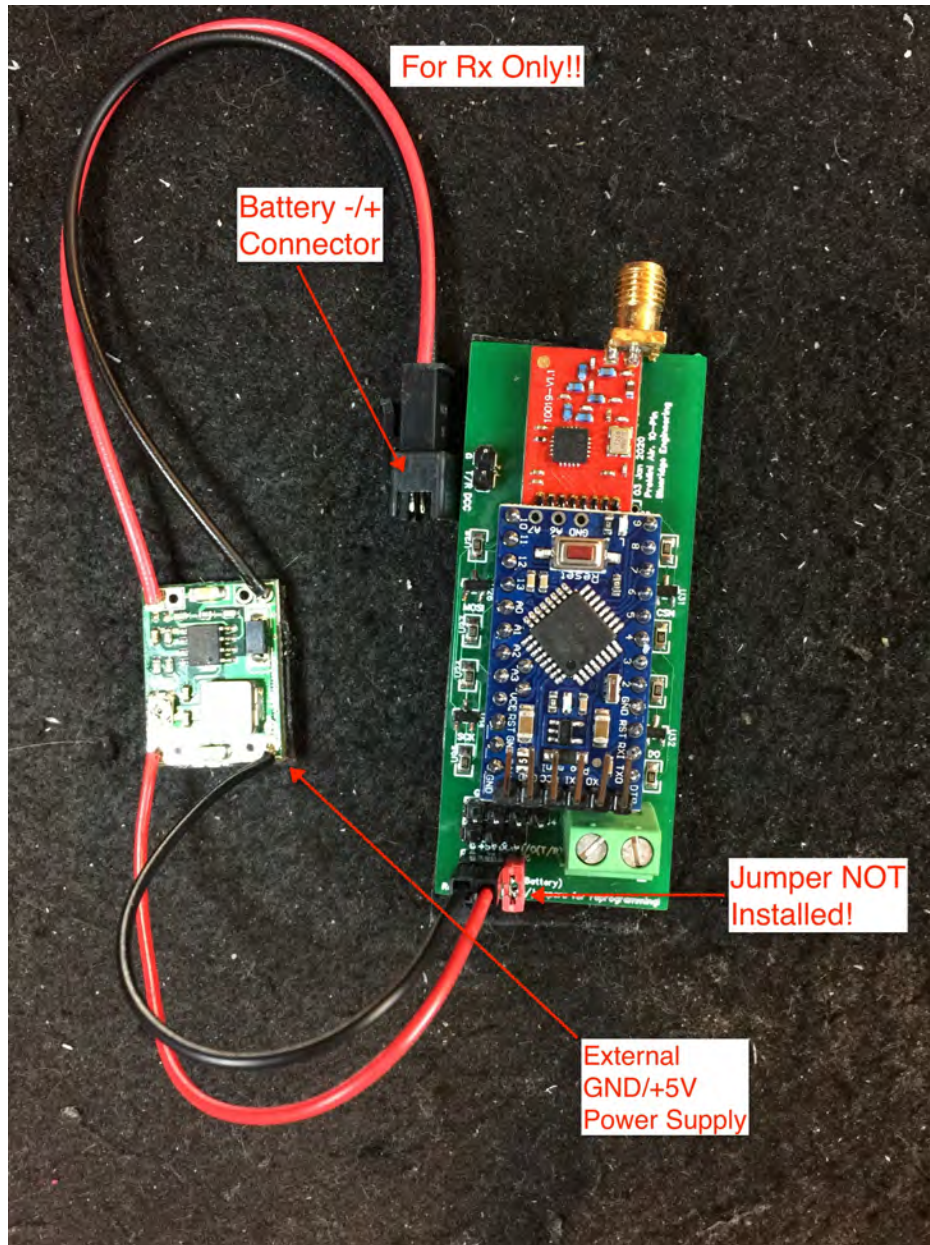


Figure 14: ProMini Air receiver powered by an external +5V power supply (older PMA version, but the connections are the same for newer versions)

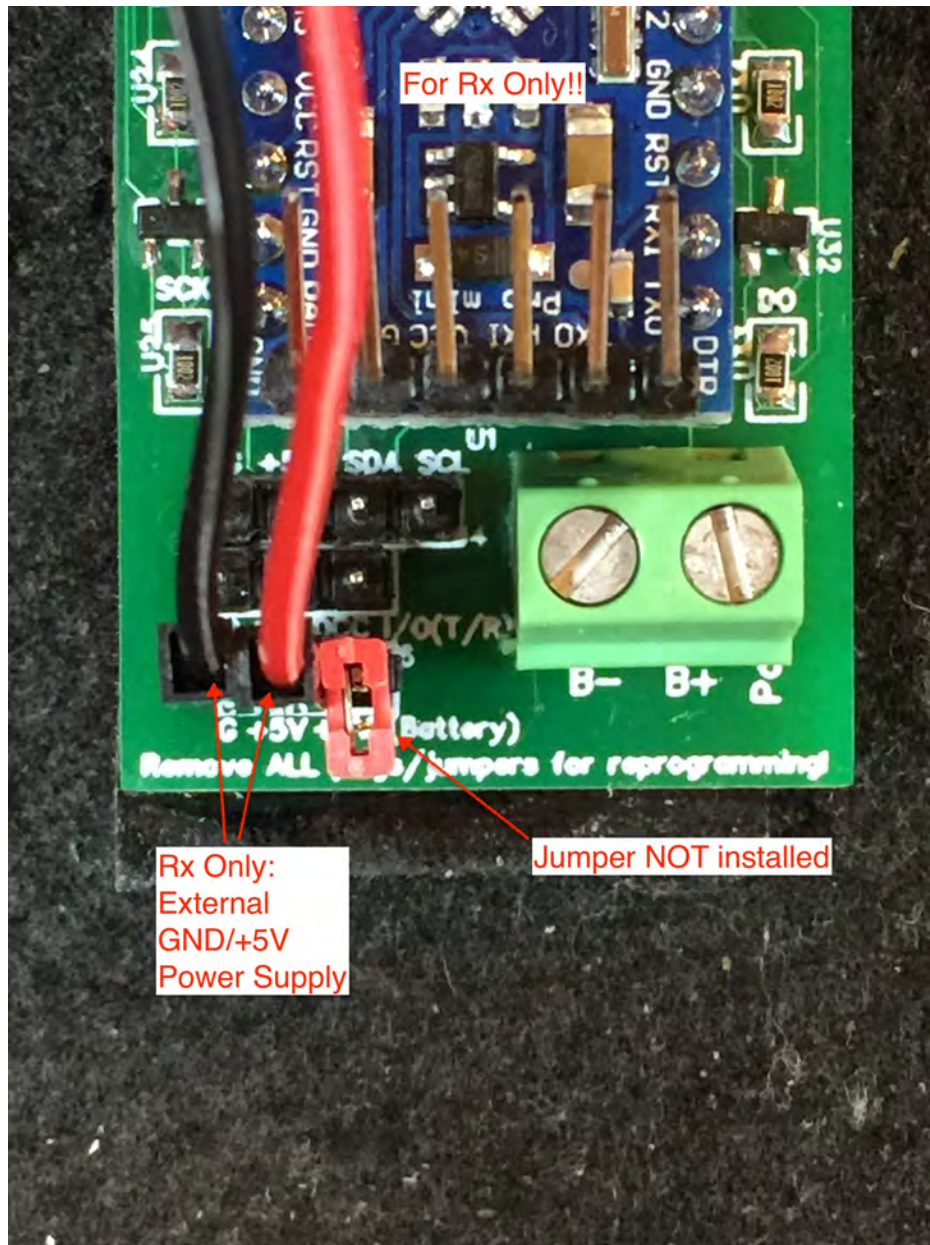


Figure 15: Close-up of ProMini Air receiver power connections to an external +5V power supply (older PMA version, but the connections are the same for newer versions)

Depending on the particulars of your installation, the author will provide an appropriate DCC amplifier as part of your PMA Rx purchase.

Some DCC amplifiers have their specialized connector configurations, as shown in Figure 17, for a GROVE-compliant amplifier

5.3 Integration of the ProMini Air Receiver into a Locomotive

Of course, the real purpose of the ProMini Air receiver is to integrate it into a locomotive for wireless DCC control using an onboard battery as power. An excellent high-power (13A continuous) DCC amplifier may be purchased [here](#), as shown in Figure 18. This Cytron MD13S amplifier is the one we provide with the ProMini Air receiver unless determined otherwise for size constraints. You can successfully use more expensive high-amperage amplifiers (about \$30 US as of 2020) found at Pololu [here](#) or [here](#). These amplifiers are smaller (0.8" x 1.3") than the Cytron.

An example installation is shown in Figure 19.

6 RF Receiver Compatibility

We have successfully tested the ProMini Air transmitter with several wireless, RF receivers, operating in the 902–928 MHz Industrial, Scientific, and Medical (ISM) band that are designed to interface with onboard DCC decoders:

- Airwire CONVRTR series
- QSI Solutions Gwire
- Tam Valley Depot DRS1, MkIII and MkIV
- Stanton Cab (S-Cab) receivers such as the LXR-DCC
- NCE D13DRJ wireless DCC decoder
- OScaleDeadRail ProMini Air receiver.

We have also verified that the ProMini Air transmitter works in the European ISM band at 869.85MHz with the Tam Valley Depot DRS1, Mk IV, receiver. This is Channel 18 on the ProMini Air transmitter (and receiver).

6.1 Airwire CONVRTR Series

The company [CVP](#) manufactures and supports its Airwire series of products that include hand-held wireless DCC-compliant throttles (such as the T5000 and T1300) and receivers,

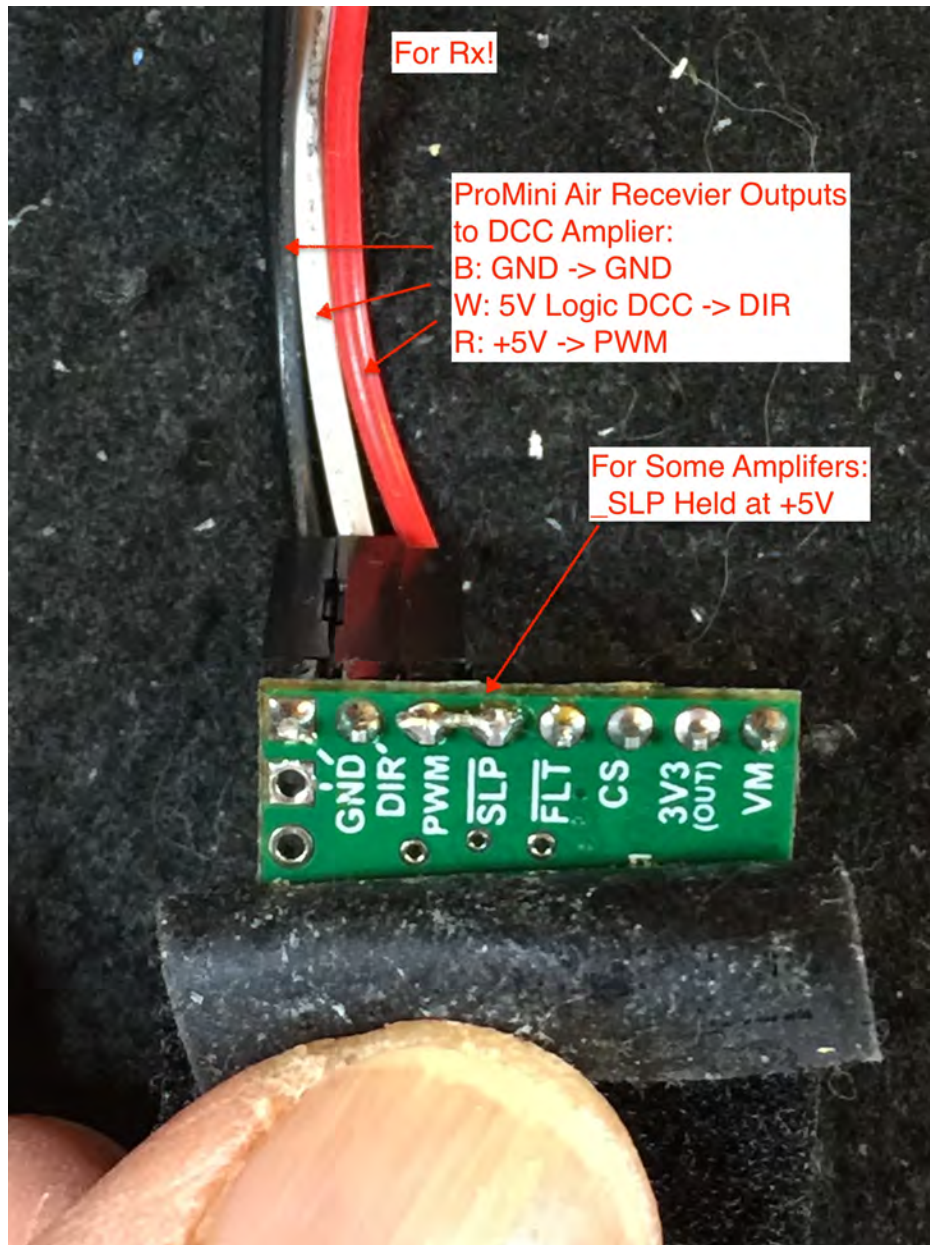


Figure 16: Close-up of the inputs to the DCC amplifier from the ProMini Air receiver

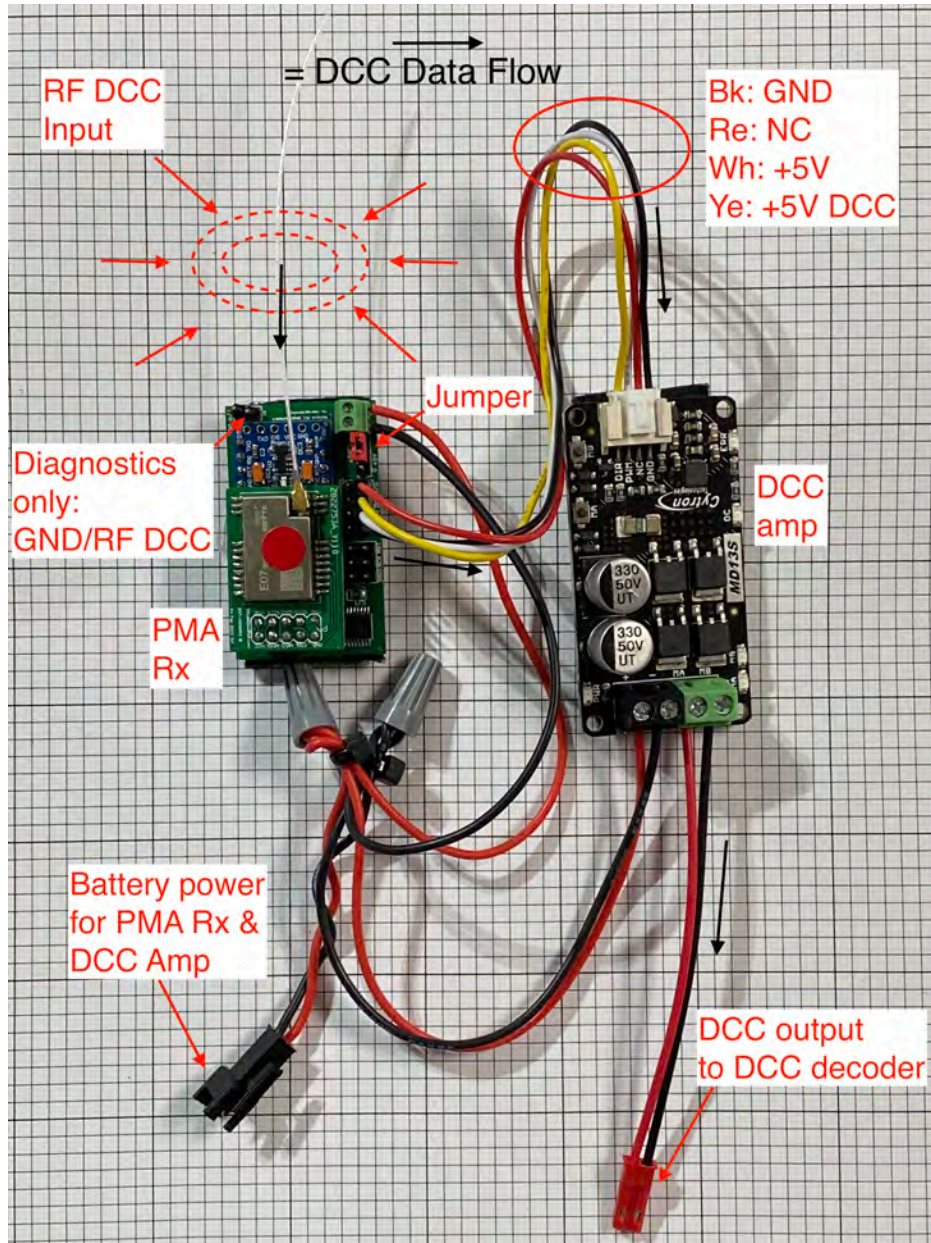


Figure 17: Example of another DCC amplifier's connections to the ProMini Air receiver

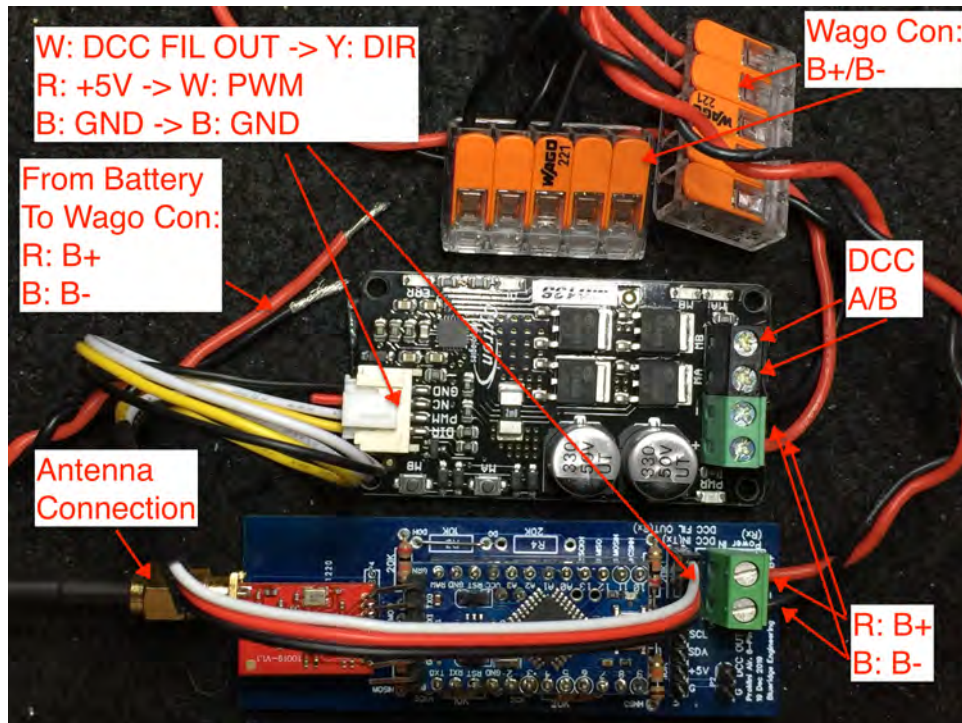


Figure 18: ProMini Air receiver integration with battery power, DCC amplifier, and antenna (older PMA version, but the connections are the same for newer versions)

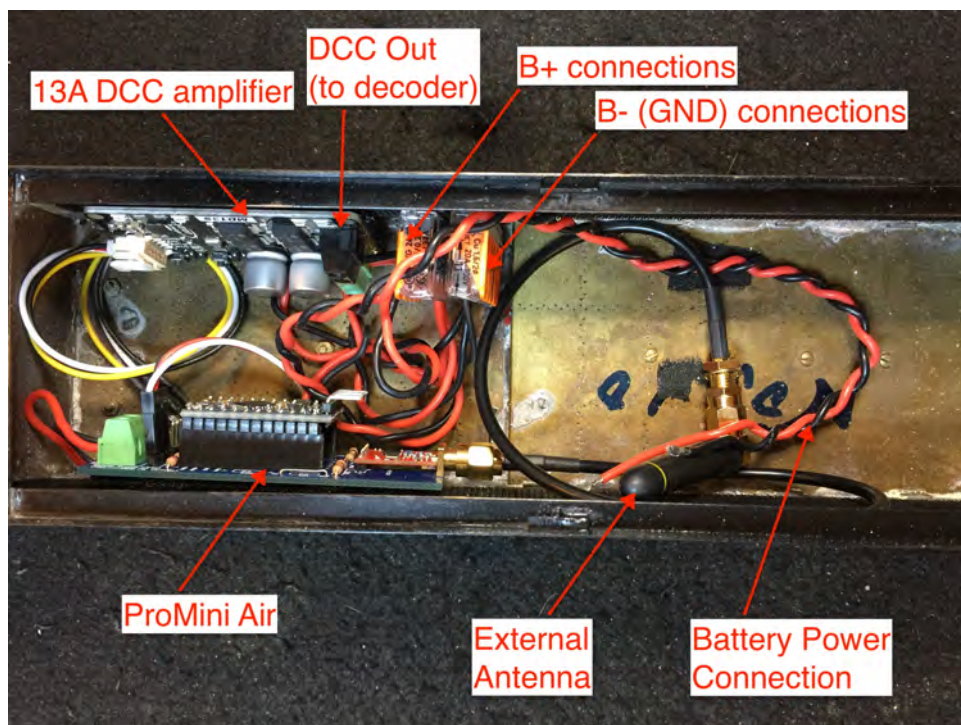


Figure 19: Example Installation

such as the CONVRTR series that seamlessly connects to DCC decoders onboard the locomotive. As a general comment, CVP provides excellent, detailed installation and operation documentation and that's in part why they are dominant in some segments of wireless model railroad control. The CONVRTR receiver has some sophisticated features, such as setting its Airwire RF channel purely in software, as described in its [User Guide](#).

However, the CONVRTR interacts with the Airwire wireless throttles in ways that make it challenging to transmit “garden variety” DCC wirelessly to the CONVRTR for proper operation. The Airwire wireless throttles send numerous DCC “IDLE” packets as a “keep-alive” message for the CONVRTR. A red LED on the CONVRTR board indicates received signal quality and flickers least when receiving numerous DCC IDLE packets. The *brightness* of the LED is an indication of received RF power. Typical DCC throttles are not designed with these concerns in mind and do not output DCC IDLE packets often enough to keep the CONVRTR “happy.”

To combat this problem, the ProMini Air transmitter software intercepts “garden variety” DCC from the throttle and attempts to interleave a sufficient number of DCC IDLE packets to maintain communication with the CONVRTR. The Airwire CONVRTR’s “keep-alive” requirement for numerous IDLE packets is challenging, so sometimes a reset of the DCC throttle or the ProMini Air is required to send enough DCC IDLE packets to initiate communication with the CONVRTR.

This “keep-alive” feature of automatically inserting DCC “IDLE” packets may in unusual circumstances interfere with operation, so it can be turned OFF by setting the throttle’s address to the ProMini Air’s DCC address, and in “OPS” mode setting CV244 to “1” (or any other valid non-zero value, see Table 1). However, if Automatic IDLE Insertion is turned OFF (CV244≠0), then Airwire receivers will probably not operate correctly with signals produced by the ProMini Air transmitter.

Turning off Automatic IDLE Insertion *may* be necessary in cases where the “Service Mode” operation is required to reprogram some features of an onboard decoder. We encourage the user to leave Automatic IDLE Insertion ON (CV244=0) and try “Service Mode” reprogramming before resorting to turning off Automatic IDLE Insertion (CV244≠ 0. We caution the user that “Service Mode” commands will be sent wirelessly to *all* “listening” wireless decoders because “Service Mode” does *not* use a specific DCC address! So, all wireless DCC receivers should be turned *off* except for the single “target” for “Service

Table 2: RF Receiver Summary

Name	Channels	Antenna	RF Loss Output	CV27 Relevant?
CONVRTR	0-16	Int or U.FL	DC	Yes
Gwire	0-7	Wire or U.FL	Pulses	No
DRS1, MkIII	16, 17	Wire	Pulses	No
DRS1, MkIV	0-17,18	Int or U.FL	Pulses	No
S-Cab LXR-DCC	17	Int	DC	Yes
NCE D13DRJ	16, 17	Int	Pulses	No
ProMini Air	0-17,18	SMA or U.FL	DCC Idle/DC*	No/Yes*

Int=Internal, *software configurable

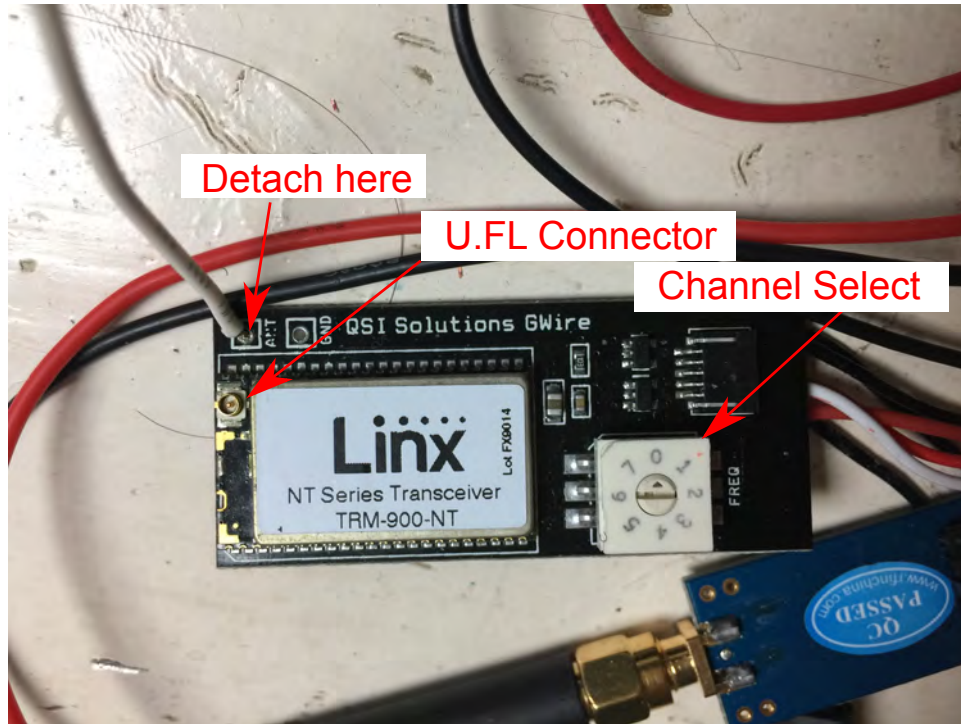


Figure 20: Gwire U.FL connector. If using the U.FL connector, detach the wire antenna.

Mode” reprogramming. Note that most decoder reprogramming can be done in “OPS” mode, which will send reprogramming commands to a specific DCC address, so resorting to “Service Mode” should be a last resort.

Like the Gwire receiver below, the Airwire CONVRTR has a U.FL connector for connecting a shielded antenna cable from the receiver to an externally-mounted antenna. An internal antenna option is available as well for CONVRTR mountings that are not surrounded by metal.

6.2 QSI Solutions Gwire

The Gwire receiver operates on Airwire RF channels 0-7, which must be selected from a dial on the device itself and is a suitable wireless DCC receiver for the ProMini Air. A nice feature of this receiver is an onboard U.FL connector (see Figure 20) that allows the user to connect a shielded antenna cable between the receiver and an externally-mounted antenna. The U.FL connector is useful when the antenna must be mounted on the exterior of a metal locomotive or tender shell. See Blueridge Engineering’s website [here](#) and [here](#) for details on how to interface the Gwire to any onboard DCC decoder. The Gwire presents no difficulties for the ProMini Air transmitter, and you can find it on eBay at reasonably low prices.



Figure 21: Tam Valley Depot DRS1, MKIII in an open-cavity install. Note the built-in long wire antenna.

6.3 Tam Valley Depot DRS1, MkIII

The DRS1, MkIII receiver operates only on Airwire RF channel 16 (actually, 916.49 MHz, which is close enough to Airwire channel 16 at 916.37 MHz) and makes a suitable wireless DCC receiver. This receiver has a long, single-wire antenna that provides efficient RF reception (see Figure 21). However, the user should place this wire outside any metal shell, which may be inconvenient in some mounting applications. The DRS1, MkIII, presents no difficulties for the ProMini Air transmitter. The DRS1, MKIV, described in the next section, supersedes this receiver.

6.4 Tam Valley Depot DRS1, MkIV

The DRS1, MkIV, receiver completely departs from the DRS1, MkIII. It operates at the original Tam Valley 916.48 MHz frequency (S-Cab channel 17), Airwire Channels 0-16, and the European ISM band at 869.85MHz (channel “18”). The DRS1, MkIV, comes with either an internal antenna or a U.FL plug connecting to an external antenna. The DRS1, MkIV presents no difficulties for the ProMini Air transmitter. This receiver is an interesting choice because it changes channels automatically until it finds sufficient RF signal carrying DCC packets. See Figures 22 and 23.



Figure 22: The recently-released Tam Valley Depot DRS1, MkIV receiver. Note the internal antenna on the right side of the board.

6.5 NCE D13DRJ Wireless Decoder

The [NCE D13DRJ](#), now, sadly, discontinued, is a dead-rail DCC decoder that originally touted compatibility with the [Stanton Cab](#). The decoder's documentation is found [here](#). As can be seen in Figure 24, the decoder is tightly-integrated with the receiver.

The NCE D13DRJ uses the same receiver chip (the [Linx RXM-916-ES](#) operating at 916.48MHz) as the older Tam Valley Depot Mk III receiver. The NCE D13DJR has been verified to work with the ProMini Air transmitter on Airwire Channel 16 (916.37MHz) or Channel 17 (916.48MHz).

6.6 Stanton S-Cab Receivers

The Stanton Cab (or S-Cab) is a series of dead-rail transmitters and receivers developed and sold by dead-rail pioneer Neil Stanton, Ph.D. S-Cab products are available at [this site](#)

Stanton offers a hand-held transmitter, the [S-Cab Throttle](#), specifically designed to transmit to S-Cab RF receivers. These receivers include the S-CAB Radio Receiver (LXR-DCC) and Loco Receivers for HO, On3, On30, and some S-scale installations. Also, Stanton will provide an S-Cab receiver coupled with decoders for larger scales. The available options are discussed on the S-Cab website [here](#).

The S-Cab Throttle and receivers operate at 916.48MHz or 918.12MHz (single frequency only!). The former frequency is close to Airwire Channel 16 (916.36MHz), and

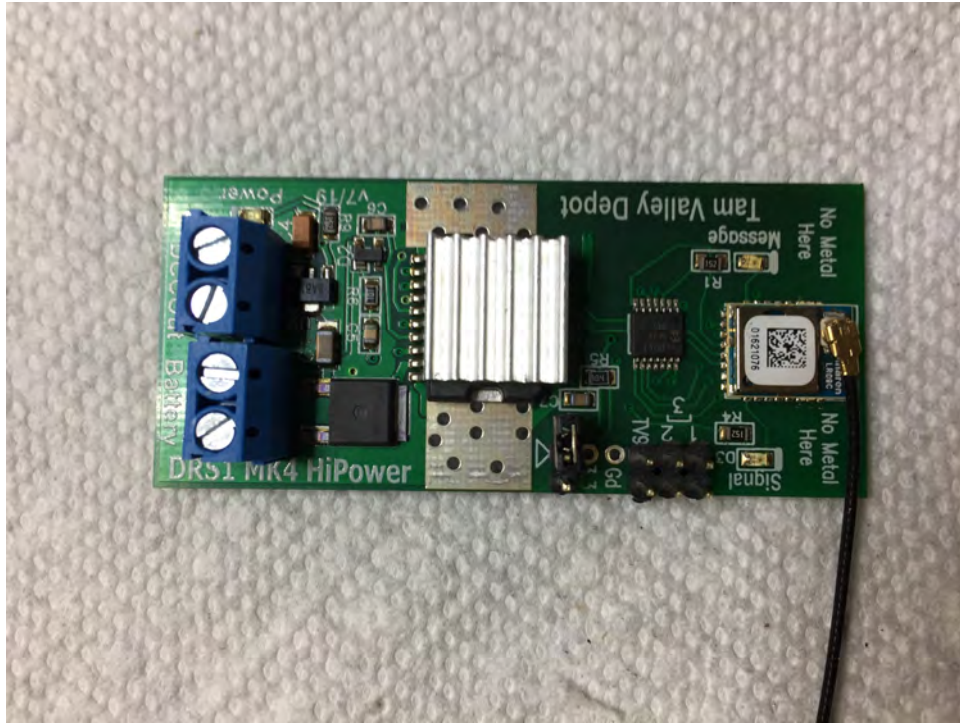


Figure 23: The recently-released Tam Valley Depot DRS1, MkIV receiver with a U.FL plug for connecting to an external antenna.

the latter is the same frequency as Airwire Channel 11. However, Airwire hand-held transmitters *WILL NOT WORK* with S-Cab receivers at either Channel 16 or 11. And Airwire receivers *WILL NOT WORK* with the S-Cab Throttle.

We have devised the RF settings that allow the ProMini Air transmitter (PMA Tx) to operate with the S-Cab receivers (such as the LXR-DCC, Figure 25), and these settings are now added an S-Cab compatible Channel 17. This addition required moving the European Channel 17 to Channel 18. See Figure 26 for a demonstration of the PMA Tx transmitting to the S-Cab LXR-DCC receiver.

6.6.1 Operating the S-Cab Throttle with the PMA Rx

The specialized RF settings for Channel 17 also allow the S-Cab Throttle to transmit to the ProMini Air receiver (PMA Rx) with just a tiny wrinkle to establish communication (more about this below).

Since the S-Cab Throttle transmits on Channel, the PMA Rx must use its automatic “channel search” capability to “find” the S-Cab Throttle’s intermittent transmissions on this Channel with it’s unique RF settings.

The S-Cab Throttle’s intermittent transmissions are where the “wrinkle” occurs. The PMA Rx’s channel search after power on quickly searches for transmissions in the following channel sequence: 0(A), 18(E), 17 (S-Cab), 1(A), 2(A), 3(A), ..., 16(A), where



Figure 24: The NCE D13DRJ wireless decoder

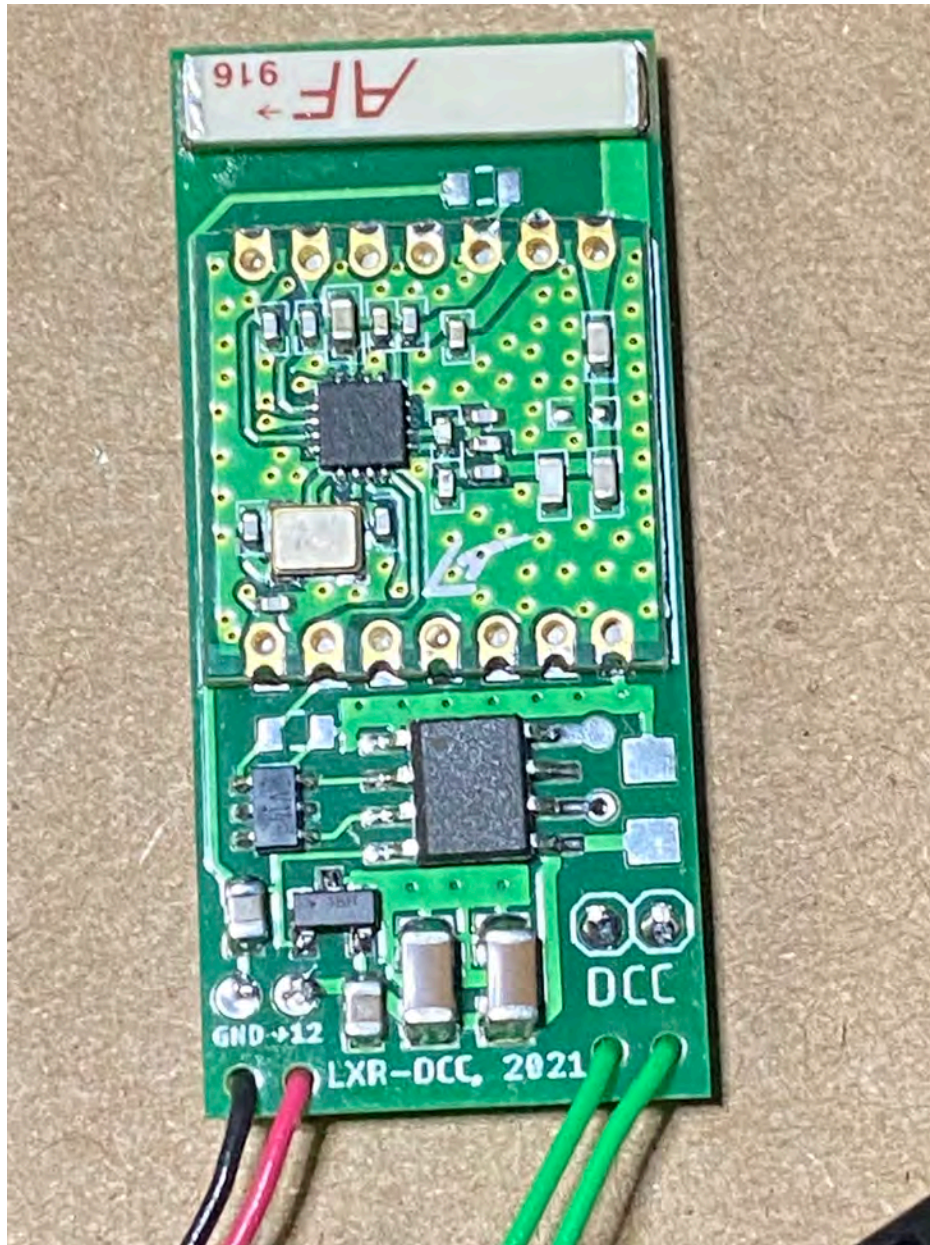


Figure 25: The S-Cab LXR-DCC receiver with a built-in antenna.

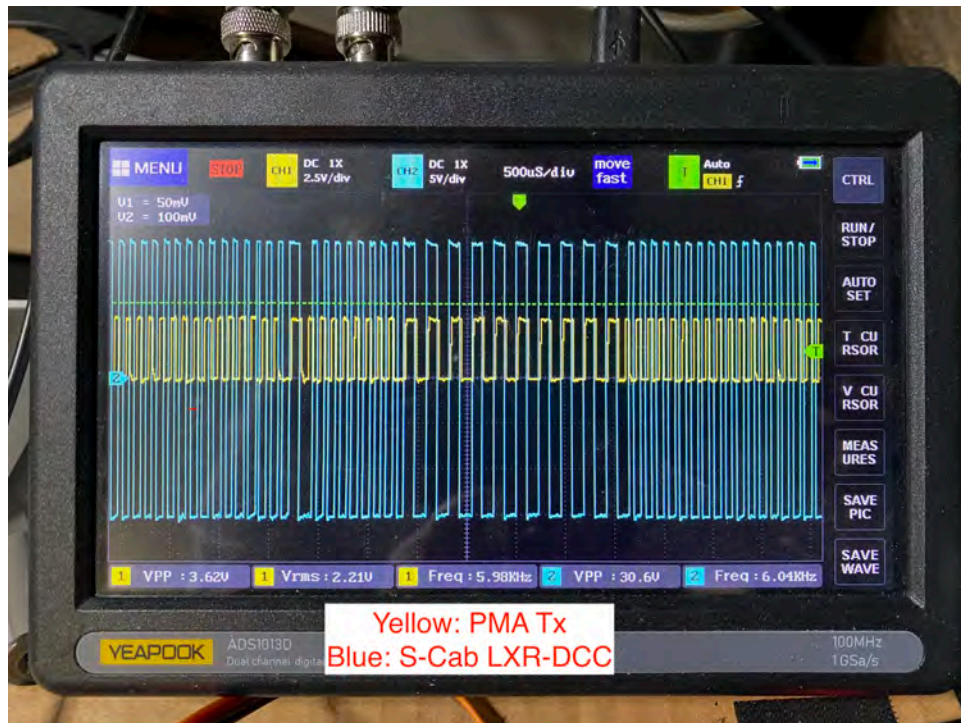


Figure 26: Demonstration that the ProMini Air transmitter (yellow waveform) successfully transmits to the LXR-DCC receiver (blue waveform) on Channel 17. Note the very slight time delay of the LXR-DCC's waveform.

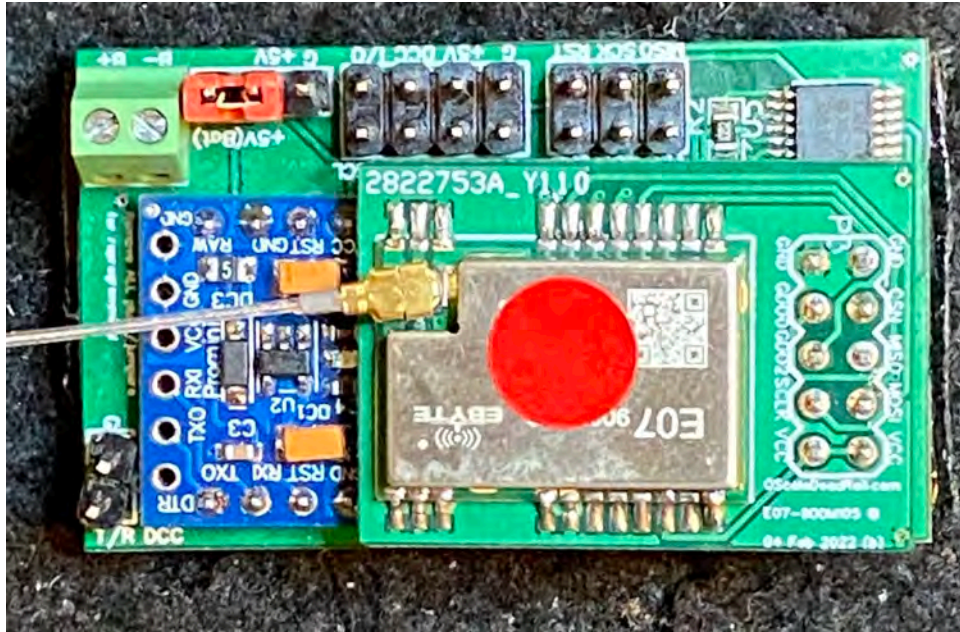


Figure 27: The ProMini Air receiver with a U.FL antenna.

(A) mean Airwire channel, (E) means European ISM frequency 869.85MHz, and (S-Cab) means for S-Cab at 916.48MHz with other specialized settings.

The S-Cab Throttle’s transmissions are intermittent, so if the operator does nothing, the S-Cab Throttle might not be transmitting in the short time window when the PMA Rx is looking for transmissions on Channel 17. To force the S-Cab Throttle into nearly continuous transmissions, slide the speed control up and down continuously for several seconds while the PMA Tx is powering up to guarantee the PMA Tx has transmissions on Channel 17. If the PMA Tx does not “sync up” with the S-Cab Throttle, try again by turning the PMA Tx off and then back on while sliding the S-Cab’s speed control up and down.

The Channel 17 settings are devised for S-Cab products operating at 916.48MHz. Contact the author should you need this interoperability at 918.12MHz.

6.7 OScaleDeadRail ProMini Air Receiver

The inexpensive ProMini Air receiver presents no issues when used with the ProMini Air transmitter. This receiver operates on Airwire RF channels 0–16, S-Cab channel 17, or the European ISM band at 869.85MHz (channel “18”) and requires a separate amplifier to convert the ProMini Air’s unipolar 5V DCC to bipolar DCC that provides sufficient power to the decoder.

6.8 Receiver and Decoder Behavior with Loss of RF

The designers of various DCC-compatible RF receivers have a several of strategies for what output to provide to the onboard DCC decoders when a valid RF signal is lost:

1. Output the random pulses that the RF receiver naturally outputs when a valid RF signal is lost. This option will cause most DCC decoders to maintain direction and speed while the DCC decoder “sifts” the random pulses searching for valid DCC packets.
2. Output a fixed, positive Direct Current (DC) voltage to one of the DCC decoder’s “Track” inputs and a zero voltage DC the other “Track” input when either a) valid RF signal is lost or b) for some RF receivers such as the Airwire CONVRTR do not receive “keep-alive” DCC packets often enough from the RF transmitter. How the DCC decoder responds to these DC “Track” inputs depends upon DCC decoder configuration and, unfortunately, DCC decoder manufacturer discretion.
3. Output a DCC “Idle” message that keeps the decoder “happy” and continues its current operating state.

There are several NMRA-specified *Configuration Variables* (CVs) that affect how decoders handle the loss of valid DCC packets, which is important to understand when using the ProMini Air transmitter because the RF receivers may lose or receive corrupted RF signal from the ProMini Air transmitter.

The NMRA standard [S-9.2.4](#), Section C “Occurrence of Error Conditions” [3] describes “Multi-Function Digital Decoder shall have a Packet Update time-out value.” Further down on line 60, the standard states, “A value of 0 disables the time-out (i.e., the user has chosen not to have a time-out)”. This part of the NMRA standard is *not* universally implemented by manufacturers, and it affects how decoders will respond to the loss of RF transmission of DCC packets. To implement this requirement, the NMRA standard [NMRA standard S-9.2.2](#) [2] has defined the “recommended”, but *not* “mandatory”, CV11, Packet Time-Out Value. A value of CV11=0 is defined to turn off the time-out, but CV11 is frequently *not* implemented.

However, another CV that *is* often implemented addresses some aspects of the loss of DCC. The “optional” CV27, Decoder Automatic Stopping Configuration is under re-evaluation by NMRA, but the NMRA has taken no definite action for some time. Here is what the NMRA standard [2] currently (as of 2019) states about CV27:

Configuration Variable 27 Decoder Automatic Stopping Configuration

Used to configure which actions will cause the decoder to stop automatically.

Bit 0 = Enable/Disable Auto Stop in the presence of an asymmetrical DCC signal, which is more positive on the right rail.

“0” = Disabled “1” = Enabled

Bit 1 = Enable/Disable Auto Stop in the presence of an asymmetrical DCC signal, which is more positive on the left rail.

“0” = Disabled “1” = Enabled

Bit 2 = Enable/Disable Auto Stop in the presence of an Signal Controlled Influence cutout signal.

“0” = Disabled “1” = Enabled

Bit 3 = Reserved for Future Use.

Bit 4 = Enable/Disable Auto Stop in the presence of reverse polarity DC.

“0” = Disabled “1” = Enabled

Bit 5 = Enable/Disable Auto Stop in the presence forward polarity DC.

“0” = Disabled “1” = Enabled

Bits 6-7 = Reserved for future use.

Since DCC decoder manufacturers frequently *do* implement CV27, what electrical output the DCC-compatible RF receiver provides to the DCC decoder upon loss of a valid RF signal will influence how the DCC decoder responds. We will break this down for various brands of DCC-compatible RF receivers *in the 902-928 MHz ISM band* in the following subsections.

Note that some DCC decoders will *not* honor CV27=0; i.e., all auto-stopping features *disabled*. For example, with CV27 set to 0, the [Zimo MX-696](#), and probably other Zimo DCC decoders as well, will continue speed and *forward* direction if *positive* DC level is input to the “*Right Track*” DCC input, and a zero DC level is input to the “*Left Track*” DCC input. Under these “track voltage” conditions, the locomotive will *stop* if originally moving *backward*. Some (but not all) DCC-compatible RF receivers, such as the Airwire CONVRTR, provide these DC inputs if a valid RF signal is lost, but only if connected correctly.

The “correct” connection relates to how the user connects the DCC output from the RF receiver to the “Track Right” and “Track Left” inputs of the DCC decoder. Under normal circumstances, when there is a valid RF signal, which way the DCC decoder connects to the RF receiver does *not* matter. Under the exceptional case of DC-only output by the RF receiver, if it loses a valid RF signal, which way the DCC decoder connects to the RF transmitter *does* matter. The user will likely want the locomotive to continue *forward* with the loss of a valid RF signal, so some experimentation is required to determine which of the RF transmitter DCC outputs should connect to which of the DCC decoder’s “Track” inputs to achieve the desired behavior.

As a further complication, we recommend that the user *turn off* the decoder’s “analog” mode of operation by setting Bit 2 of CV29 to 0 to force the decoder to use “NMRA Digital Only” control of “Power Source Conversion” (see [2]). If Bit 2 of CV29 is set to 1, and again we emphasize the user should probably *not* activate this feature, then “Power Source Conversion Enabled” and then CV12 determines the power source; the most common of which is CV12=1, “Analog Power Conversion.”

6.8.1 Airwire CONVRTR Series

When the CONVRTR loses a valid RF signal or receives insufficiently frequent DCC IDLE packets, it detects these conditions and sends a fixed DC voltage to the decoder. Consequently, the user *should* set CV27 according to the description above.

While it seems that you would want the locomotive to stop if its RF receiver loses a valid RF signal, consider what might happen in tunnels or remote locations. Getting stuck under these circumstances if a valid RF signal is lost is probably not what the user wants, so we strongly suggest that the user set CV27=0.

The user is cautioned, however, that some DCC decoders, such as the new [ESU Lok-Sound 5 L DCC](#), do *not* honor the CV27=0 setting unless the decoder's "Track Right/Left" is connected "correctly" to the CONVRTR's "A/B" output. Experimentation may be required to determine the correct connection, but my experience is the following: CONVRTR A <-> Decoder Track Right & CONVRTR B <-> Decoder Track Left.

6.8.2 Stanton Cab LXR-DCC Receiver

If the S-Cab LXR-DCC loses valid RF reception, it will output a DC voltage. Depending on which of the LXR-DCC's output are connected to which DCC track input to the decoder, this DC voltage will be considered as "positive" or "negative" DC voltage, and the decoder will respond depending on the decoder's configuration. Consequently, like the CVP Airwire CONVRTR, the user *should* set CV27 according to the description above.

6.8.3 NCE D13DRJ

The NCE D13DJR wireless decoder is tightly integrated with its Linx RXM-916-ES receiver. By default, the decoder will maintain direction and speed, and lighting outputs when it loses valid RF signals.

6.8.4 QSI Solutions Gwire and Tam Valley Depot DRS1 Series

The [QSI Solutions Gwire](#) and [Tam Valley Depot DRS1, MkIII and MkIV](#) DCC-compatible RF receivers will output random pulses to the onboard DCC decoder when a valid RF signal is lost, so setting CV27 is probably of no use. On the "plus" side, most DCC decoders will maintain locomotive direction and speed in the presence of these random pulses since the DCC decoder is actively sorting through these pulses for valid DCC packets, which is usually the behavior the user wants.

This Blueridge Engineering [webpage](#) describes how to modify the GWire for use as an RF receiver easily for any onboard DCC decoder.

6.8.5 OScaleDeadRail ProMini Air Receiver

The [OScaleDeadRail](#) ProMini Air receiver has a default long address of 9901. Like the ProMini Air transmitter, the ProMini Air's receiver's channel can be reset in "OPS Mode" by setting CV255 to a value in the range of 0—16. The ProMini Air receiver has the following options when a valid RF signal is lost:

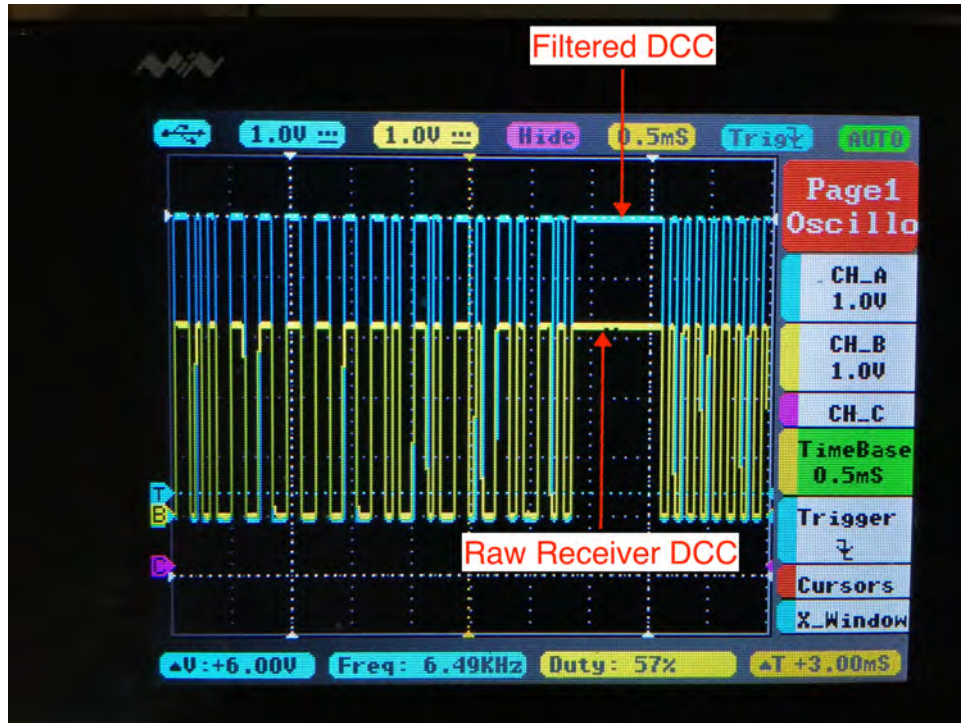


Figure 28: ProMini Air's raw transceiver and filtered DCC outputs with valid RF DCC signal

- Output a DCC “Idle” message that will keep the decoder “happy.” The decoder will continue to operate in its current state, including maintaining its current speed and direction.
- Output either fixed positive or negative voltage DC to the onboard DCC decoder: In this case, setting CV27 for the onboard DCC decoder at *its* address *is* relevant. The user can set the ProMini Air receiver to output fixed DC voltage when it loses a valid RF signal by setting CV246 to 1 in “OPS mode” at the ProMini Air's address. A positive DC voltage is output by setting the ProMini Air receiver's CV248 to 1 in “OPS mode” at the ProMini Air's address or a negative DC voltage is output by setting CV248 to 0. If the user does not want the locomotive to stop with the loss of a valid RF signal, then set CV27=0 for the onboard DCC decoder at *its* address. Of course, setting CV27 to other values (see above) in the DCC decoder will determine how the DCC decoder responds to the fixed DC voltage that the ProMini Air outputs to the onboard DCC decoder upon loss of a valid RF signal.

See Figures 28, 29, and 31 for how the ProMini Air can be configured.



Figure 29: ProMini Air's raw transceiver and filtered DCC outputs (DCC "Idle") with no valid RF DCC signal and filtering off (CV246=0).



Figure 30: This is the output produced by the Gwire and Tam Valley Depot receivers with no valid RF DCC signal.

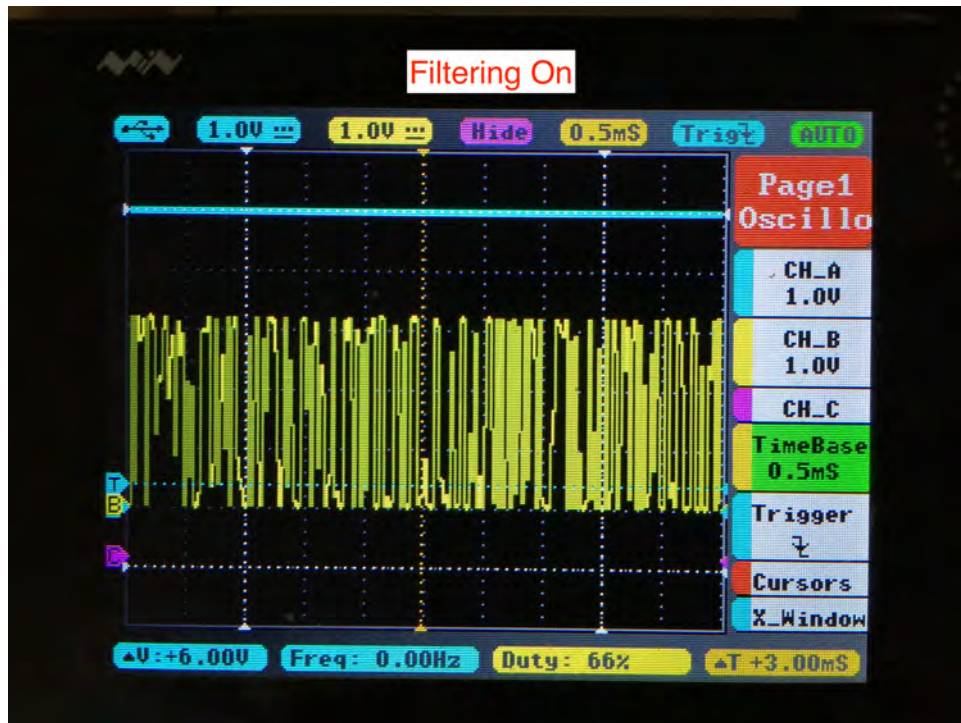


Figure 31: ProMini Air's raw transceiver and filtered DCC outputs with no valid RF DCC signal and filtering on (CV246=1, CV248=1). This is the output produced by the Airwire CONVRTR as well.

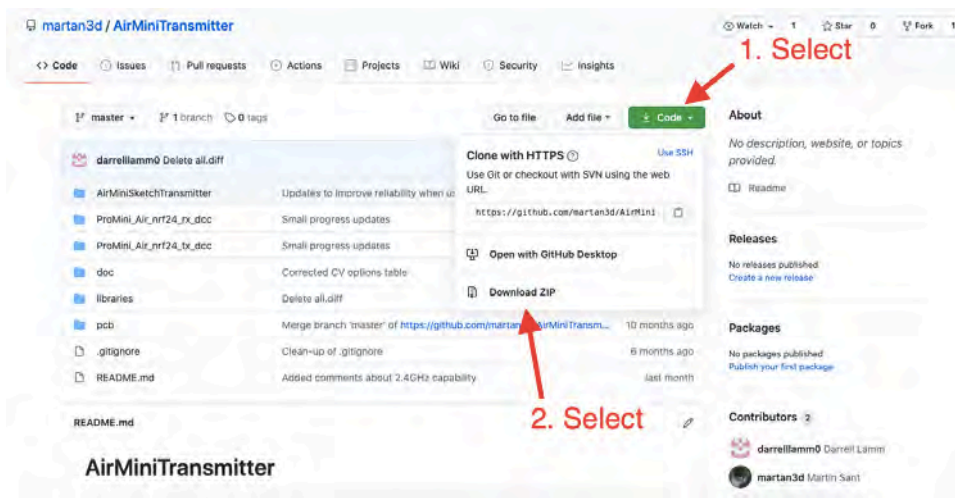


Figure 32: How to download the GitHub zip file that will maintain the directory structure

A Firmware Installation

The ProMini Air Tx and Rx are provided with the firmware already loaded. These instructions are for advanced users who want to update the firmware.

The source code is available from this [GitHub site](#). Locate the source code in a directory where the Arduino IDE can find it. You should retain the subdirectory structure to access the “project” with the Arduino IDE.

Depending on whether you want a transmitter or receiver, edit [config.h](#) to select the “define” for the transmitter or receiver.

For a receiver (Rx), config.h should look like this:

```
// #define EU_434MHz
/* For World-Wide 2.4GHz ISM band*/
// #define NAEU_2p4GHz

////////////////////////////////////
// Set Transmitter or Receiver
////////////////////////////////////
/* Uncomment ONLY ONE #define*/
/* For receiver*/
#define RECEIVER
/* For transmitter*/
// #define TRANSMITTER

////////////////////////////////////
// Set the default channel for NA/EU 900MHz only!
////////////////////////////////////
#if defined(NAEU_900MHz)
/* Uncomment ONLY ONE #define*/
/* To set the default to NA channel 0 for 869/915MHz ISM bands only!*/
#define NA_DEFAULT
/* To set the default to EU channel 18 for 869/915MHz ISM bands only!*/
// #define EU_DEFAULT
#endif
```

```

////////////////////////////////////
// Set the transceiver's crystal frequency
////////////////////////////////////
/* Uncomment ONLY ONE #define*/
/* For 27MHz transceivers (e.g., Anaren 869/915MHz (CC110L) and Anaren 869MHz (CC1101) radios)*/
// #define TWENTY_SEVEN_MHZ
/* For 26MHz transceiver (almost all other radios, including Anaren 433MHz (CC1101), 915MHz (CC1101), and 2.4GHz (CC2500) radios)*/
#define TWENTY_SIX_MHZ
...

```

If you want a transmitter (Tx), then config.h should be the following:

```

// #define EU_434MHz
/* For World-Wide 2.4GHz ISM band*/
// #define NAEU_2p4GHz

////////////////////////////////////
// Set Transmitter or Receiver
////////////////////////////////////
/* Uncomment ONLY ONE #define*/
/* For receiver*/
// #define RECEIVER
/* For transmitter*/
#define TRANSMITTER

////////////////////////////////////
// Set the default channel for NA/EU 900MHz only!
////////////////////////////////////
#if defined(NAEU_900MHz)
/* Uncomment ONLY ONE #define*/
/* To set the default to NA channel 0 for 869/915MHz ISM bands only!*/
#define NA_DEFAULT
/* To set the default to EU channel 18 for 869/915MHz ISM bands only!*/
// #define EU_DEFAULT
#endif

////////////////////////////////////
// Set the transceiver's crystal frequency
////////////////////////////////////
/* Uncomment ONLY ONE #define*/
/* For 27MHz transceivers (e.g., Anaren 869/915MHz (CC110L) and Anaren 869MHz (CC1101) radios)*/
// #define TWENTY_SEVEN_MHZ
/* For 26MHz transceiver (almost all other radios, including Anaren 433MHz (CC1101), 915MHz (CC1101), and 2.4GHz (CC2500) radios)*/
#define TWENTY_SIX_MHZ
...

```

Two further options are available. The first option selects the crystal frequency of the FCC/EC-approved transceiver: 27MHz (Anaren) or 26MHz (Ebyte). The second option specifies North American or European default use.

After you complete downloading the firmware into the Pro Mini, please do not remove the USB connection from the computer until the “secondary” LED, which indicates attempted communication over the SPI (serial peripheral interface), flashes on (it will not be bright). This step ensures you properly initialize the EEPROM!

You load the firmware into the Pro Mini MCU using an “AVR ISP,” such as the Sparkfun Pocket AVR Programmer or a less-expensive clone. This “ISP” downloading mode will bypass and erase the bootloader to directly load the firmware into the Pro Mini MCU. On boot-up with the bootloader now erased, the Pro Mini MCU will almost instantly supply “5V logic DCC” to the DCC amplifier, which provides the DCC decoder with standard DCC waveforms. There is no “boot-up DC” and no need to set CV29, bit2=0. (I set it anyway.) With this solution, all DCC decoders I’ve tried (ESU, Zimo, MTH) startup without the “boot-up jerk.”

This “ISP” form of loading firmware is not as extensively used by folks using the Arduino IDE, but ISP loading is easily accessible within the Arduino IDE. The overly-brief method of ISP programming steps are the following:

1. Remove the transceiver daughterboard and the jumper (if inserted).

2. Connect the USBtinyISP (or other) Programmer (with power switch ON to supply 5V DC to the ProMini Air PCB while programming) to the 6-pin connector on the ProMini Air.
3. From the Arduino IDE, Select Tools → Programmer → “USBtinyISP” (or whatever ISP programmer you are using).
4. Select the AirMiniSketchTransmitter sketch.
5. Select Sketch → Upload using a Programmer. The Arduino IDE will compile the sketch and download the resulting firmware to the Pro Mini via the USBtinyISP, bypassing (and erasing) the bootloader.

Once the ProMini Air receiver or transmitter firmware is installed in the Pro Mini and inserted into the ProMini Air PCB, the ProMini Air is ready for integration as described in Section 5!

References

- [1] Anonymous. Communications Standards For Digital Command Control, All Scales. NMRA Standard S9.2, National Model Railroad Association, Inc., National Model Railroad Association, Inc., P.O. Box 1328, Soddy Daisy, TN 37384-1328, July 2004. <https://www.nmra.org/sites/default/files/s-92-2004-07.pdf>.
- [2] Anonymous. Configuration Variables For Digital Command Control, All Scales. NMRA Standard S9.2.2, National Model Railroad Association, Inc., National Model Railroad Association, Inc., P.O. Box 1328, Soddy Daisy, TN 37384-1328, July 2012. https://www.nmra.org/sites/default/files/standards/sandrp/pdf/s-9.2.2_decoder_cvs_2012.07.pdf.
- [3] Anonymous. Fail-Safe Operating Characteristics For Digital Command Control, All Scales. NMRA Standard S9.2.4, National Model Railroad Association, Inc., National Model Railroad Association, Inc., P.O. Box 1328, Soddy Daisy, TN 37384-1328, July 2012. https://www.nmra.org/sites/default/files/s-9.2.4_2012_07.pdf.

Abbreviations/Acronyms

DCC	Digital Command Control
ISM	Industrial, Scientific, and Medical
LCD	Liquid Crystal Display
NMRA	National Model Railroad Association
RF	Radio Frequency

Glossary

- I2C** Inter-Integrated Circuit, sometimes abbreviated “IIC.” A synchronous, multi-master, multi-slave, packet switched, single-ended, serial computer bus invented in 1982 by Philips Semiconductor (now NXP Semiconductors).
- ISM Band** For the purposes of this document and for the US only, the 902–928 MHz RF band reserved for: “Operation of equipment or appliances designed to generate and use locally radio frequency energy for industrial, scientific, medical, domestic or similar purposes, excluding applications in the field of telecommunications.” Other ISM bands exist as well, both in the US and internationally.
- OPS Mode** “Operations Mode” or “Programming-On-the-Main” (PoM). The mode of a DCC throttle that can change the configuration variables for a DCC decoder at a specific address while the locomotive or device is operating.