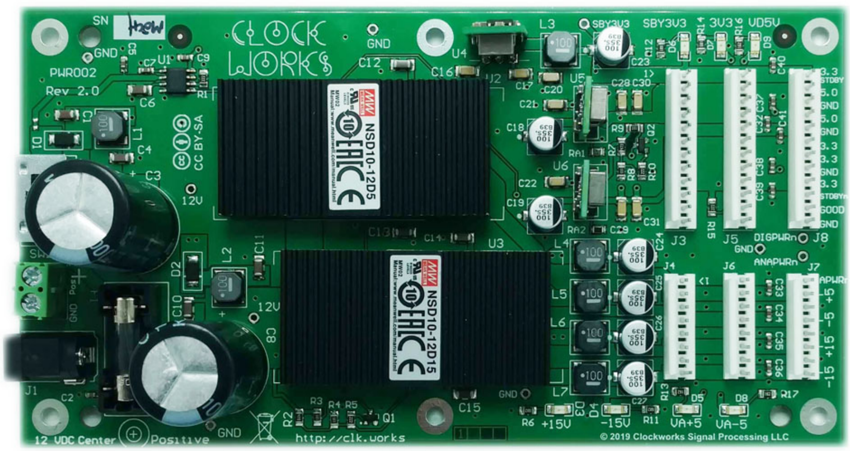
ANALOGBLOX™
SEVEN OUTPUT POWER SUPPLY
PWR002



For Revision 2 hardware

Rev 2.1

5-Dec-2019

Clockworks
Signal Processing

http://clk.works/

1. TABLE OF CONTENTS

Attachment: Schematic.

1 INTRODUCTION

The Clockworks PWR002 provides multiple voltage supplies with control options for "digital" and "analog" voltages to meet the needs of intelligent power sequencing and low power CE compliant operation in standby. Designed for use in a SignalBlox system, it is generic enough for use in any general power supply application. It's powered by a 12 VDC input and provides a peak output power totaling about 50 watts across the seven outputs. One of its more unique features is the ability to signal loss of power and hold up the outputs for up to 10 msec after loss of primary input. This allows the system controller time to ramp down volume levels and engage output muting circuitry to minimize clicks and pops on unplanned power loss.

Outputs available are:

- +3.3 Standby at 1 amp (always on output for powering standby/host controller)
- +3.3 at 3 amps, intended for use by digital circuits
- +5 at 3 amps, intended for use by digital circuits
- +/-5 at 1 amp, intended for use by analog circuits (typically ADC/DACs, and low voltage op-amps)
- +/-15V at 330 mA, intended for use by analog circuits

The supply has been designed to efficiently provide clean, low noise analog power without the need to use LDOs in the system design. Measurements performed during the design evaluation showed that analog audio systems using this supply can achieve SNR of better than 120 dB without resorting to local LDOs.

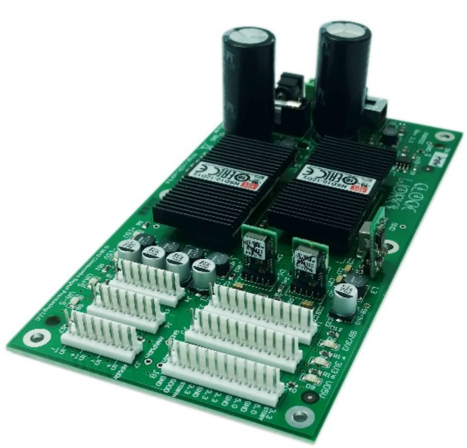


Figure 1 PWR001 module

1.1 MODULE DESCRIPTION

The PWR002 module is a 160 mm x 85 mm module with three sets of MTA-100 style connector headers for supply outputs and control. The pinouts are the same as those described in the SignalBlox System Configuration Guide.

For full details please see the schematic (at the end of this document) and associated layout files (available from the Clockworks website).

It is operated from a 12V supply via a standard 2.1mm (center positive) barrel connector or screw terminal block for discrete wire. An input diode is used to protect against reversed input supply. A 5 x 20mm 8A slow blow fuse provides a good failsafe against system damage that might occur when developing prototype systems.

Further details about the power supply design and its initial testing can be found in the TechNotes section of the Clockworks website[1].

1.2 HOW SUPPLIED

The PWR002 board is supplied in two standard configurations:

- PWR002 board only.
- PWR002 board, 12V supply (choice of North American and Universal AC plug versions for the supply), spare fuse, and three sets of MTA-100 cable assemblies

1.3 SOFTWARE SUPPORT

The PWR002 module can be controlled by the system host processor, which would use three GPIO lines to interface with the PWR002 module. One GPIO line monitors the power good signal and should cause an interrupt on loss of power. The other two GPIO lines control the analog and digital supply enables. No special software is needed, though the power fail signal should be connected as an NMI to ensure minimal delay in reacting to the loss of power.

For systems without a host processor, the analog and digital supply enable line should be jumpered low. The power fail signal can be used to directly control any available hardware muting functions.

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[1] Many of the scope captures included here are from those documents.

1.4 INPUT POWER REQUIREMENTS

Under full rated load the board provides 50W of power. With typical regulator efficiency that corresponds to about 65W of input power, or 5.5 Amps for a 12V supply. However a 5 amp supply would normally be sufficient as drawing peak continuous power from the supply is not a normal use case.

The supply design includes two 10,000 uF electrolytic capacitors at the input[2] and during a cold start situation the external supply will see a brief current spike that lasts for 1 msec and peaks at about 14A. Some small 12V supplies will trip with a load current like that and shut themselves off for a few seconds, during which time the cap discharges, causing the supply to never power up.

The Clockworks 12V supply in the kit version has been tested and found to not have issues with startup.

2 CONNECTOR & MECHANICAL INFORMATION

2.1 INPUT CONNECTORS

The input barrel connector, a CUI PJ-050AH, is configured center positive. The input voltage should nominally be 12V, but the supply can operate with 10 – 13V input range.

Alternately the Phoenix Contact 1935161 (5 mm centers) terminal block can be used with wire sizes from 14 AWG to 26 AWG.

2.2 OUTPUT CONNECTORS

There are two output connectors for power, one conforms to the 12 pin SignalBlox standard for digital power and the other the 8 pin standard for analog power. Both are from the TE[3] MTA-100 series of connectors, part numbers 1-640454-2 and 640454-8[4]. The mating part numbers (for closed end style) are 4-643813-2 and 3-643813-8. These are designed for 22AWG stranded wire, which is the largest wire size supported with MTA-100 connectors.

Table 1 and Table 2 show the pin assignments as well as the normal wire color used in the cable assemblies provided by Clockworks. For more information on the Clockworks cable assemblies look up part numbers CA002 (12 pin) and CA001 (8 pin).

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[2] A cap is there as a simplistic/low cost way to hold up the outputs to allow analog outputs to be gracefully muted during an unexpected loss of power. It also provides some filtering of the 12V supply, though its higher ESR/ESL doesn't help for high frequency noise.
[3] Formerly Tyco Electronics.
[4] These have a tab to ensure alignment when used with the mating connector with tabs. It does not have the locking ramp as extensive force is needed to unmate the connectors if that was used.

Table 1 : 12 pin digital power connector

Pin	Signal	Wire color
1	+3.3STDBY	purple
2	+5	red
3	GND	black
4	GND	black
5	+5	red
6	+3.3	orange
7	+3.3	orange
8	GND	black
9	+3.3	orange
10	DIGPOWERn	green
11	PWRGOOD	grey
12	GND	black

The DIGIPOWERn signal, when pulled low, enables the +3.3 and +5 supply outputs. The pin may driven by a OC output or an active output up to 5V. It will float to 3.3V. Input current is -0.25 mA when pulled low.

Table 2 : 8 pin analog power connector

Pin	Signal	Wire color
1	ANAPOWERn	green
2	+5	pink[5] (or brown)
3	GND	black
4	-5	white
5	GND	black
6	+15	yellow
7	GND	black
8	-15	blue

To enable the +/- 15V and +/-5V outputs the ANAPOWERn pin should be pulled low. The pin may driven by a OC output or an active output up to 5V. It will float to 3.3V. Input current is -0.25 mA when pulled low.

3 REGULATOR INFORMATION

The use of standard regulator modules allows the characteristics to be determined from their datasheets.[6] To save fishing around for those we've copied in some of the information to here.

Please note the maximum C values that are suggested. The PWR001 module has 100 uF on each output, and that should be subtracted from the numbers provided here.

3.1 MEANWELL NDS-10D15 (+/- 15V)

- Voltage tolerance: +/-2.5%
- Line regulation: +/-1%
- Load regulation: +/- 1%
- Max C: 1000 uF
- Max input current: 1.4 A

3.2 MEANWELL NDS-10D5 (+/- 5V)

- Voltage tolerance: +/-2%
- Line regulation: +/-1%

[5] Pink is an uncommon color so brown is used for this when pink is unavailable.
[6] OK, try not to laugh…power supply datasheets are all notoriously lacking in helpful information about how they might work in real circuits.

- Load regulation: +/- 3%
- Max C: 1000 uF
- Max input current: 1.4 A

3.3 MURATA OKR-T3-W12 (3.3, 5V)

- Voltage tolerance: +/-2%
- Line regulation: +/-0.3%
- Load regulation: +/- 0.5%
- Max C: 1000 uF (electrolytic, ESR > 0.015 ohms)

3.4 CUI VXO7803-1000 (3.3V)

- Voltage tolerance: +/-2% (typ), +/-4% max
- Line regulation: +/-0.2% (typ), +/-0.4% max
- Load regulation: +/-0.4% (typ), +/-0.6% max
- Max C: 680 uF

4 POWER SEQUENCING

Additional details can be found in TecnNote TN002, available on the Clockworks website. That note id for the PWR001 module but the same general timing applies to the PWR002 module.

The supply voltages all ramp to their final voltages in under 20 msec and the power good signal becomes active 70 msec later, see Figure 2. In that capture the analog enable is jumpered low. The 3.3V supply starts up in a time comparable to the +/-15V.

Load conditions will affect these numbers, and for full details the regulator datasheets should be reviewed.

The power good signal indicates the status of input power, not the voltage at the output of the regulators. If a load short is present the power good signal will still activate.

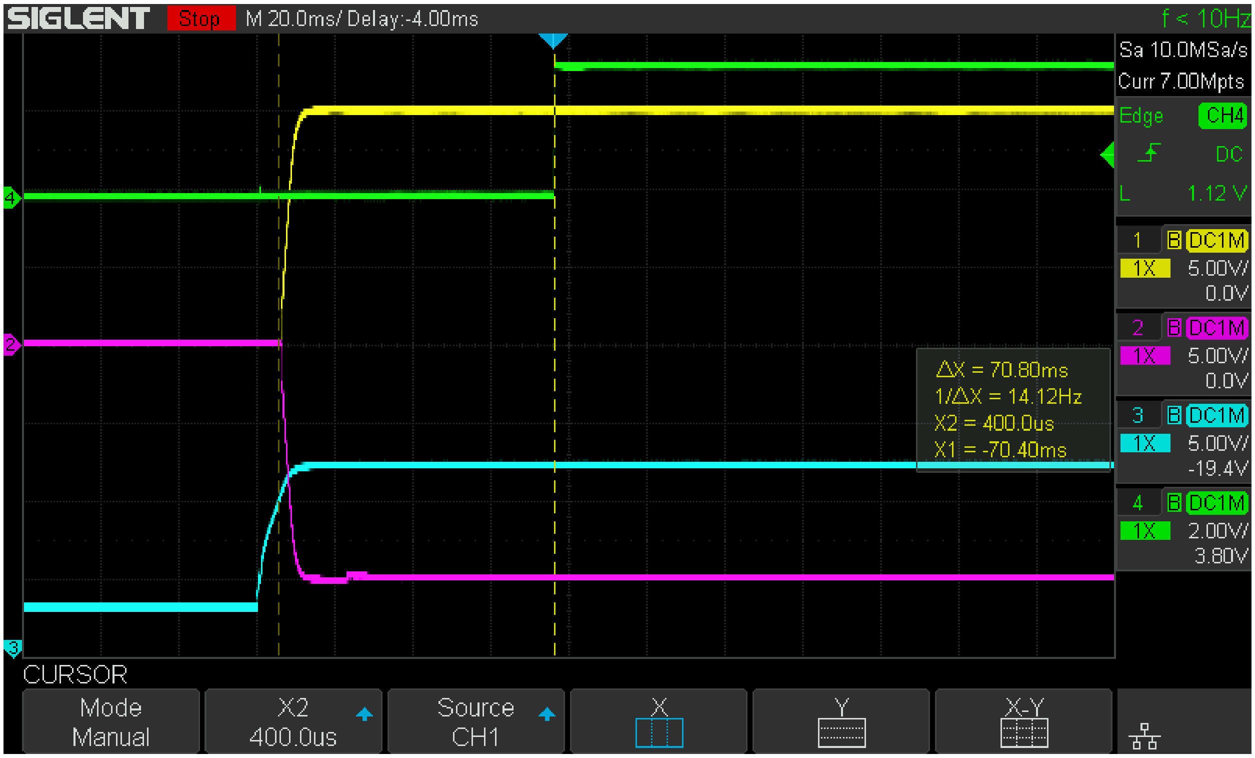


Figure 2 +15V (ch1) Yellow, -15V (ch2) Magenta, 12V in (ch3) Blue, PowerGood (ch4) Green

The amount of holdup time depends on the load. The next example, Figure 3shows the power off timing with around 7.5 watts of loading. This is for a hard power off. If the input 12V supply decays slowly this can add to the time, though as was demonstrated in TN002 it can also slightly degrade the time as the analog regulators start collapsing but the voltage supervisor has not tripped yet.

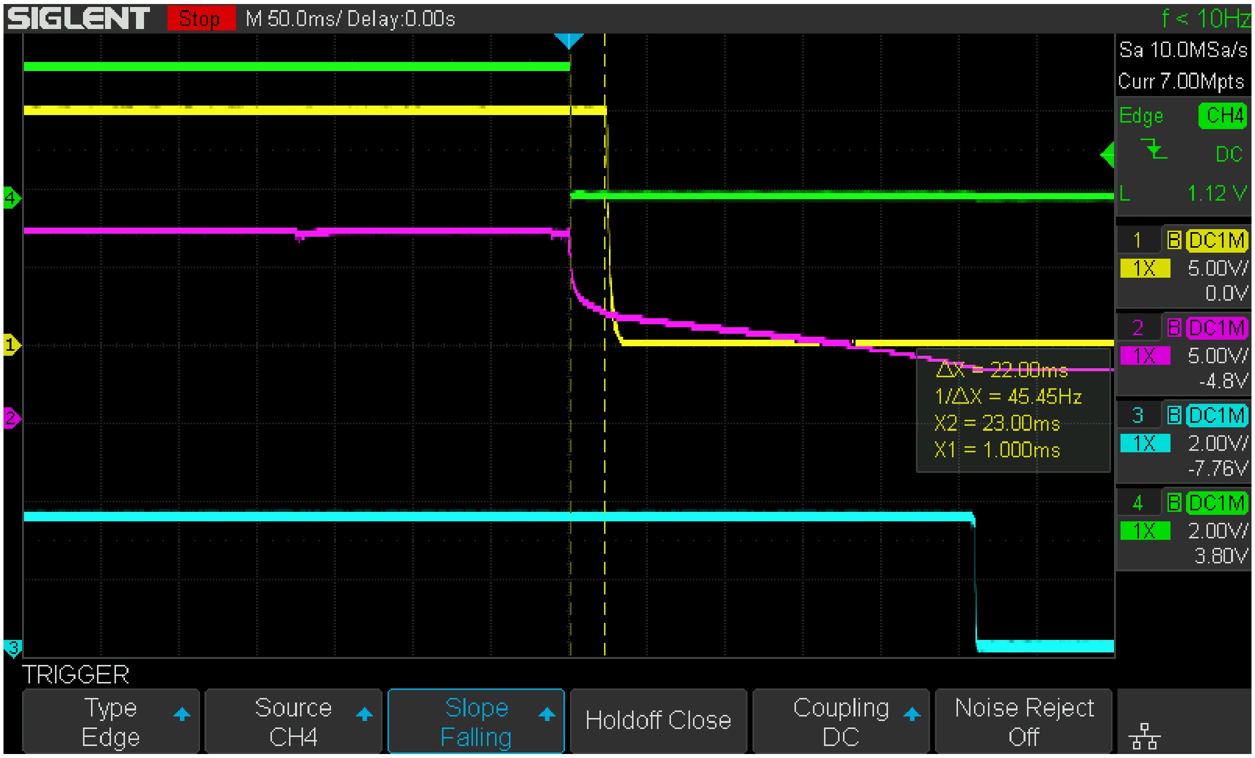


Figure 3 Switched to off. +15V (ch1) Yellow, -12V input (ch2) Magenta, 3,3V (ch3) Blue, PowerGood (ch4) Green

The +/-5 V supply is not as graceful as the +/- 15V once it falls out of regulation, as seen in the case of a 500 mA load in Figure 4. Under light loads the sawtooth is less severe, but still present. If DACs are present in the system this may need to be considered in the mute on loss of power timing.

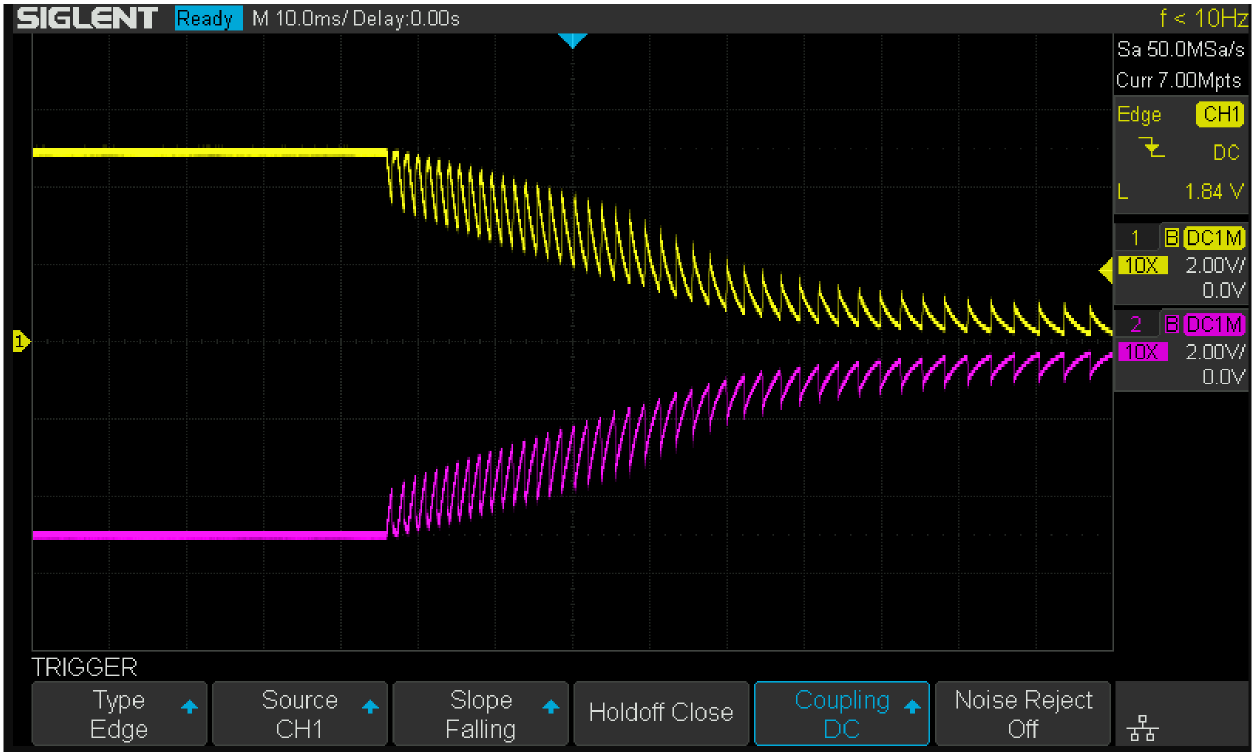
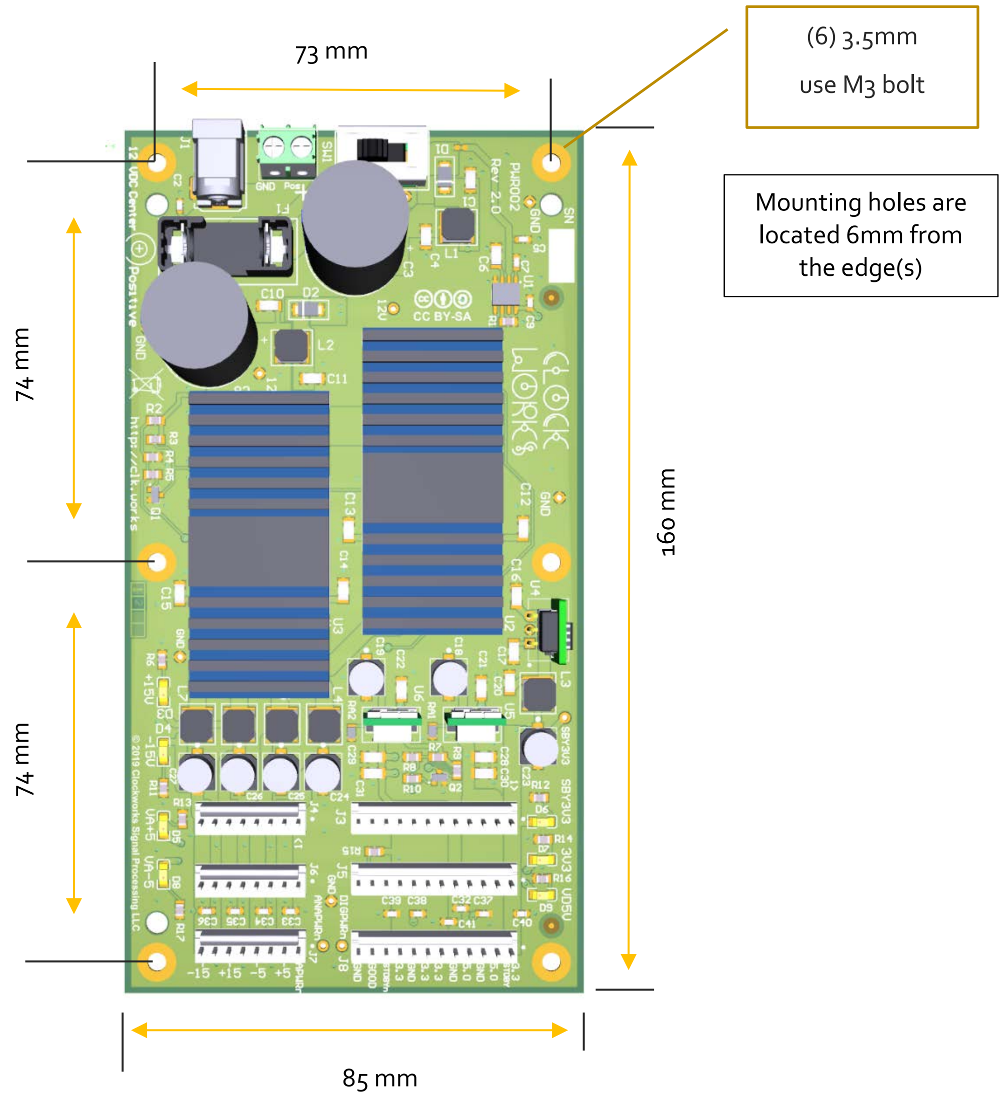


Figure 4 +/- 5V output under 500 mA load dropping out of regulation

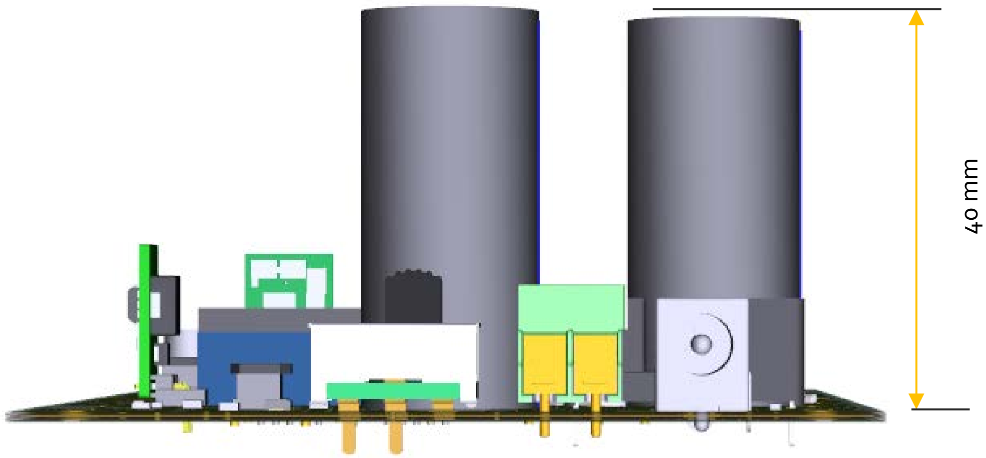
4.1 MECHANICAL

The 6 mounting holes are connected to the ground plane. The tallest component (the hold-up capacitors) top is 40mm over the board. The switch leads protrude 3mm below the board. The PCB is standard .062 (1.6mm) thickness.

Assuming typical efficiencies for a 12V supply input, the board is calculated to dissipate about 15W of power under full load conditions. It should not be placed in the airpath of other system components that create heat. Right angle mounting to allow natural convection across the board would be preferred if the board is heavily loaded.



73 mm
(6) 3.5mm
use M3 bolt
Mounting holes are located 6mm from the edge(s)
74 mm
74 mm
160 mm
85 mm



Power switch shown in
off position

5 DESIGN CONSIDERATIONS

The supply board uses a 10 uH choke and 100 uF capacitor to attenuate the switching noise from the bipolar supplies. This filter has a Fc of 5 kHz. With assumed DCR/ESR from the part's datasheets there is a bump in the simulated response around Fc as system Q is > 1, but it was not observed in the measurements.

In actual system additional decoupling capacitors would be used near the loads. However for the switching regulators to retain their load transient response there is the competing desire to minimize load capacitance. The tradeoff is further complicated by the noise spectrum of the regulators having a dependency on the current. For the logic supplies (+3.3 and +5) low frequency (i.e. audio band) noise is less of a concern. For the analog (+/- 15, +/- 5) noise in the audio band is the primary concern.

SignalBlox carriers provide additional capacitance, typically an additional 200 uF. Each module (analog or mixed signal) is assumed to place an additional 100 uF on each analog supply, though not all boards use all voltages. This places a typical additional capacitance of 400 – 600 uF on the analog supplies. This lowers Fc to around 2 kHz and the damping factor is much closer to 1.

5.1 MEASURED NOISE

These numbers are from a sample and do not indicate a guarantee of performance. They were measured with resistive loads of 200 mA on the +/-15 and 500 mA on the +/-5. TechNote 004 has further details on the regulator noise variations with load current. The + and – outputs were found to have the same noise values. Operation of the digital supply increased noise by about 0.5 dB on the +5V but no change in +15V was measured.

Measurement bandwidth is 22 kHz, unweighted measurements. A bench supply was used to provide the 12V input used to construct this table.

Supply	Capacitance added	RMS noise dBV	RMS noise uV
+15		-90	32
+15	220 uF	-92	25
+15	470 uF	-93	22
+5		-81	89
+5	220 uF	-84	63
+5	470 uF	-86	50

A number of different 12V AC adapters were also tested with the above configuration. No meaningful difference in the noise from the +15V supply was seen, but the +5V supply shows about +/-0.5 dB of variation.[7]

5.1.1 OTHER LOADS

The above table for the +/-5v is perhaps on the worst case side; with a 67 mA load the noise is around -93.5 dBv and the spectrum is lacking in the spikes seen in the measurements shown in the later section of this document.

6 GETTING STARTED WITH THE MODULE

In the kit configuration the board is supplied with a 12V power supply and 8 pin and 12 pin MTA-100 cable assemblies. Connect the MTA-100 cables to the board and your device. Ensure that the pins are lined up; there are polarizing tabs but enough force will break them off. Don't do that.

Make sure the power switch is in the off position.

Plug the 12 V supply in to the barrel connector and the plug the brick in to the AC power.

Flip the switch to the on position. The 3.3V Standby LED should illuminate. Enable the digital supplies from your target board (i.e. pull the DIGPOWERn low, OK to ground it for always on). The +3.3 and +5 LEDs should turn on. Enable the analog supplies from your target board (i.e. pull the ANAPOWERn low, OK to ground it for always on). The +/-15 and +/-5V LEDs should illuminate.

[7] Not clear why the bench supply doesn't produce the lowest noise numbers, or why the much quieter +15 doesn't show any impact.

Verify your load is receiving the correct power. If one or more of the LEDs fails to light your load may be shorting the supply rail. If all of the LEDs fail to come on verify the 12V supply is operating and check that the fuse has not blown. There is also a 12V test point on the PCB near the power switch.

6.1 OTHER THINGS

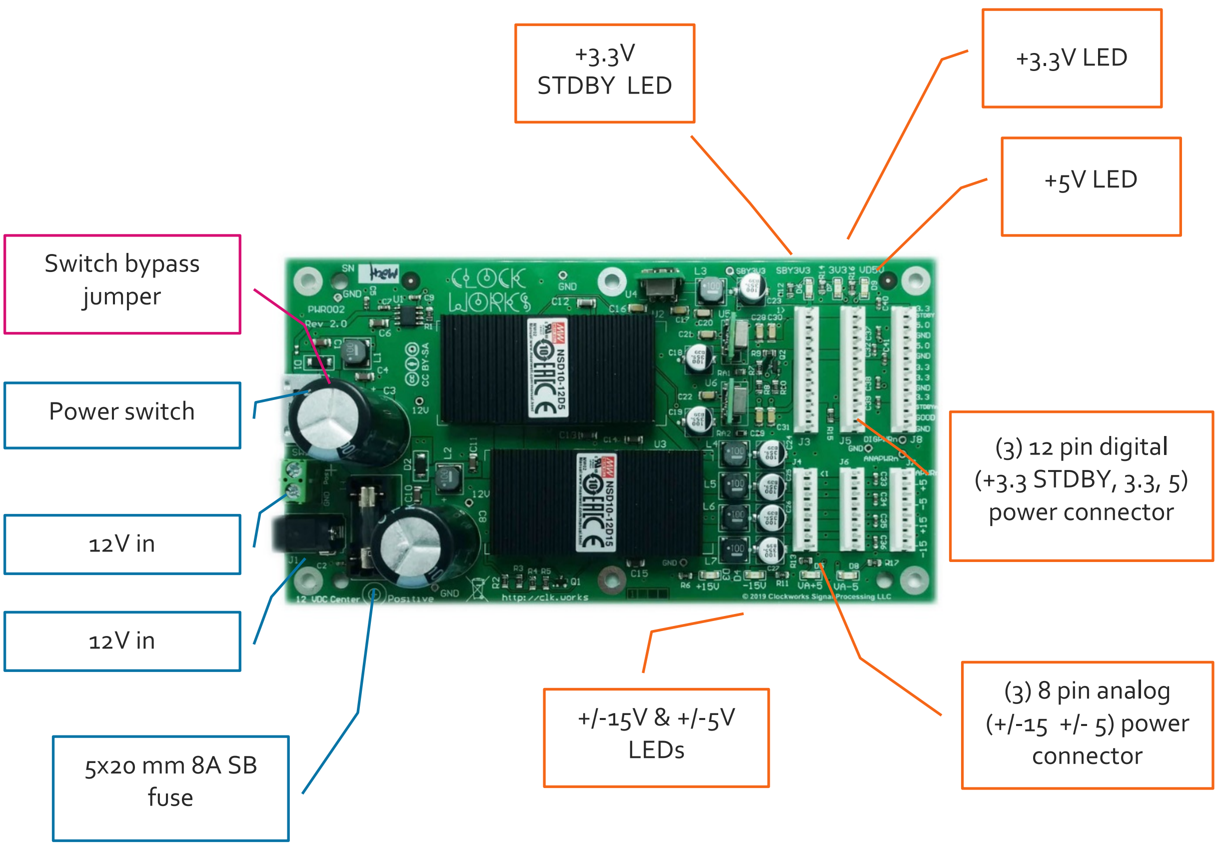


Figure 5 Board feature locations

There are a pair of jumper holes next to the switch. If the switch needs to be disabled to prevent accidental system shut off, a small wire jumper can be soldered in to the two holes next to the switch.

7 MEASURED PERFORMANCE

This section contains spectrum measurements, please see section 4.1 for noise measurements. While it's normal to expect some unit to unit variation, as well as noise measurements include things like background that will vary, these measurements can serve as a guide for determining if the supply will meet the application needs.

Plots are shown for the positive +15 and +5 supplies as measurements of the negative outputs showed similar measurements. Switching supplies' noise is not constant and will vary with load conditions; the loads used here are neither a best case nor worst case.

7.1 SUPPLY NOISE

TN003 investigated the impact of the +/- 15V supply noise on actual op-amp circuits, and TN004 investigated noise in the rev 1 version of the design, before additional filtering was added. There is some background noise in this setup, though for what's being looked for in the supply outputs this was deemed as not making a meaningful difference.

All FFTs are 16K points, with 16 averages. Vertical scale is dBu in a couple of measurements vs. the preferred use of dBv in this document[8].

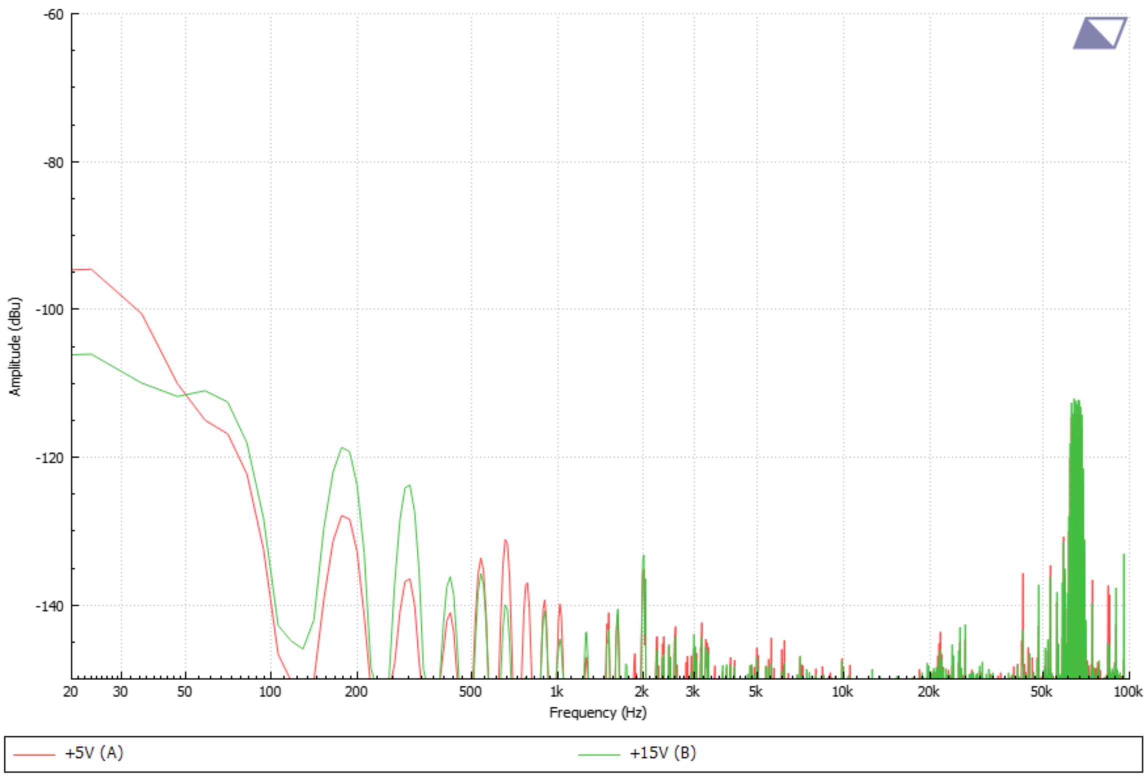


Figure 6 Residual noise pickup with supplies off

As with the earlier noise measurements the load on the +/-15V is 200 mA, and on the +/-5V is 500 mA.

[8] This seems to be a bug in the software that doesn't change the plot when the units are changed.

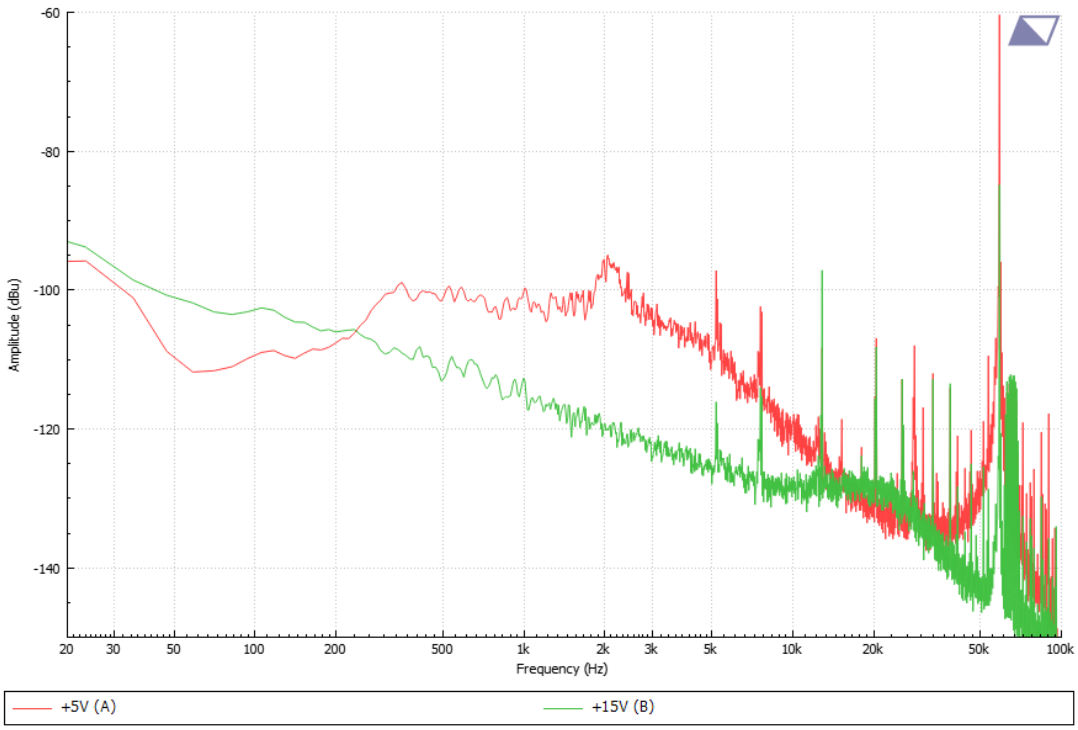


Figure 7 Bench supply powering the board, no extra capacitance.

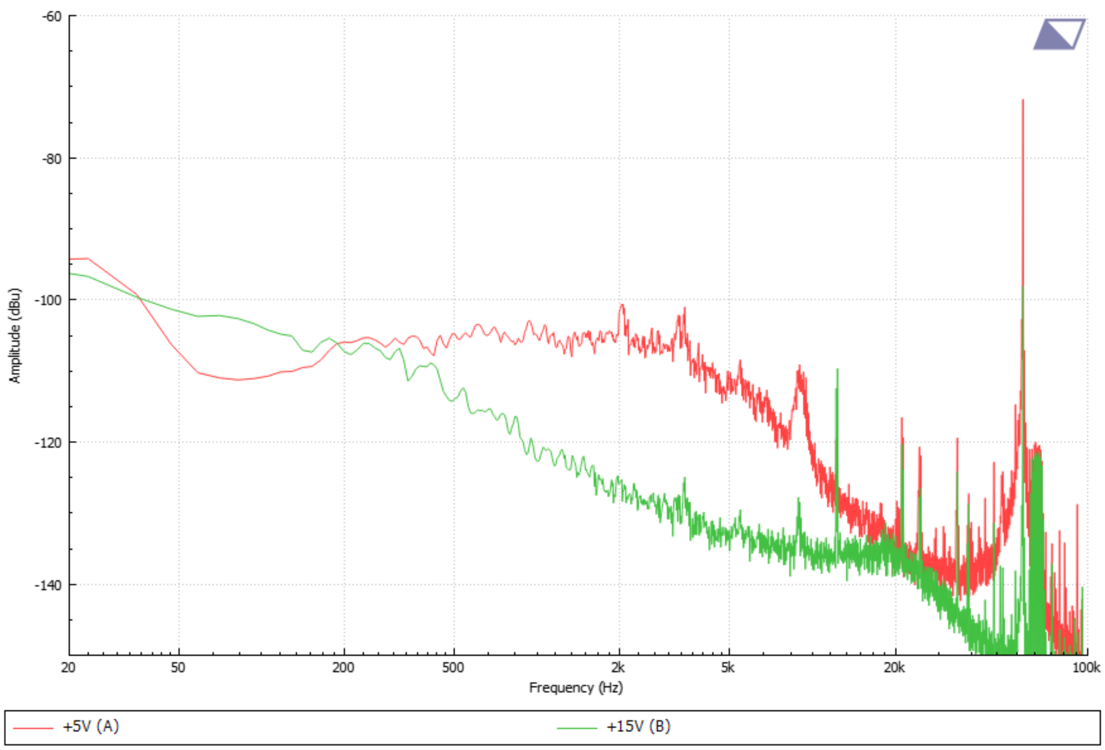


Figure 8 Bench supply powering the board, 220uF extra capacitance.

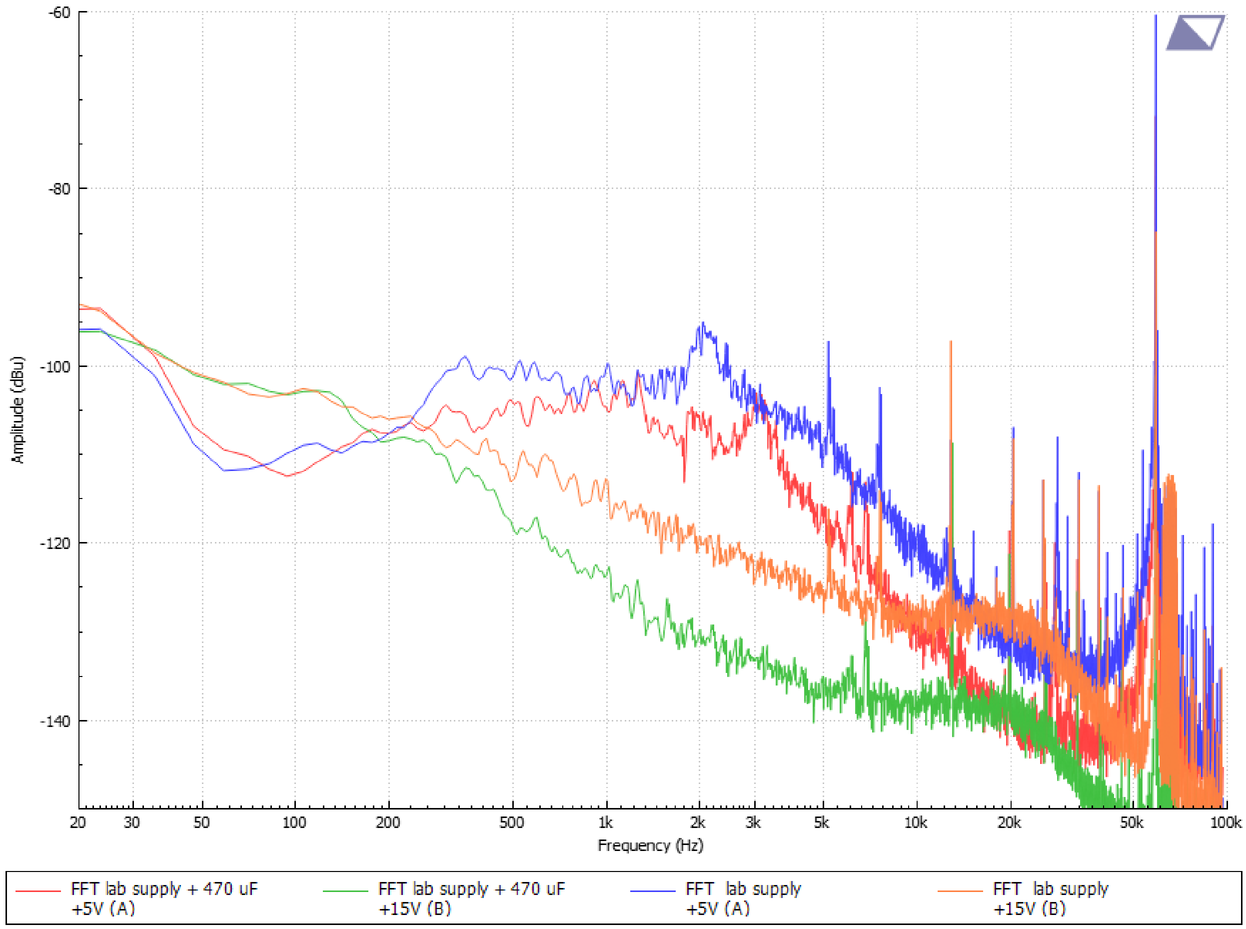


Figure 9 Comparison of 470 uF extra capacitance with no extra capacitance, with bench supply

The 59 kHz switching noise from the +5V supply is reduced from -60 dBu to -72 dBu with the capacitance added. As shown in TN004, the noise spectrum from the +/-5V module varies considerably with load.

7.2 AC SUPPLY NOISE COUPLING

One observed oddity was using the Meanwell GST series AC adapter as the power source. Though the supply noise from the PWR002 board measured about the same versus the bench supply, the spectrum above 30 kHz shows a sharp rise, see Figure 9. Since just the noise measurement was just in the audio band this isn't surprising that a supply with a lot of ultrasonic noise could appear the same. The spectrum shows the issues.

Other AC supplies did not show this problem. The path for the noise for the input supply to show up in the output is not clear; it was decided to sidestep the issue and use an AC supply that doesn't have increasing high frequency noise.

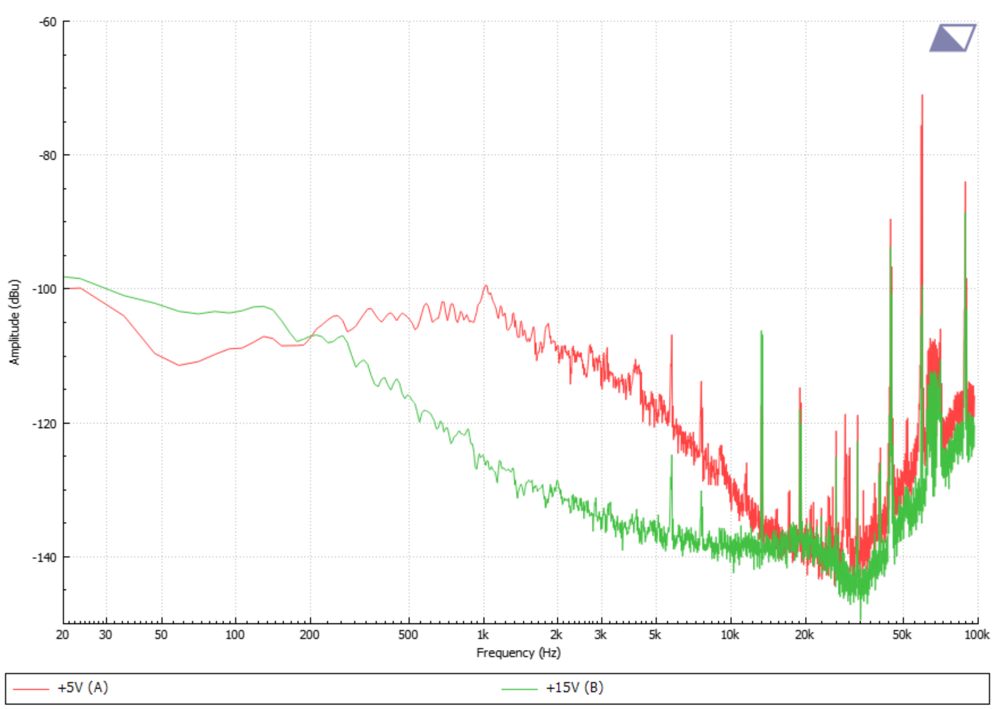


Figure 10 Nosie spectrum from Meanwell GST series AC supply

PWR002

Seven output supply for SignalBlox systems

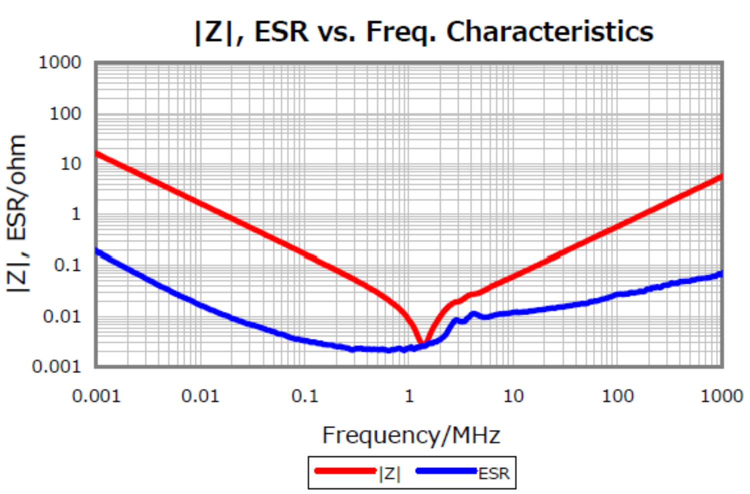
+3.3V @ 1A standby (3.3W)
+3.3V @ 3A (controlled by standby line) (10 W)
+5V @ 3A (controlled by standby line) (15W)
+/5V @ 1A (10W)
+/-15V @ 300 mA (10W)

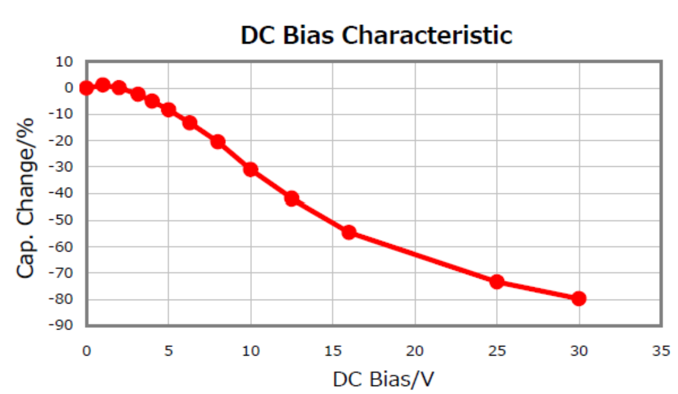
12VDC in (9V to 14V Max) @ 5A max.
Estimated dissipation worst case: 12 W

Power fail detection

max external capacitive load :
3.3V standby 600 uF
3.3, 5V 200 uF/1000 uF
+/-5, +/-15V 1000 uF

10 uF Ceramic typical ESR (TDK part)





Murata OKR-t3 cap limits

Maximum Capacitive Loading	
Cap-ESR=0.001 to 0.015 Ohms	200 µF
Cap-ESR >0.015 Ohms	1000 µF

100uF 35V 'lytic ESR approx 150 mOhm

SCHEMATIC
PWR002.main.SchDoc

SIGNALBLOX ®

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Title			
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File: PWR002.Cover.SchDoc			

CLOCKWORKS
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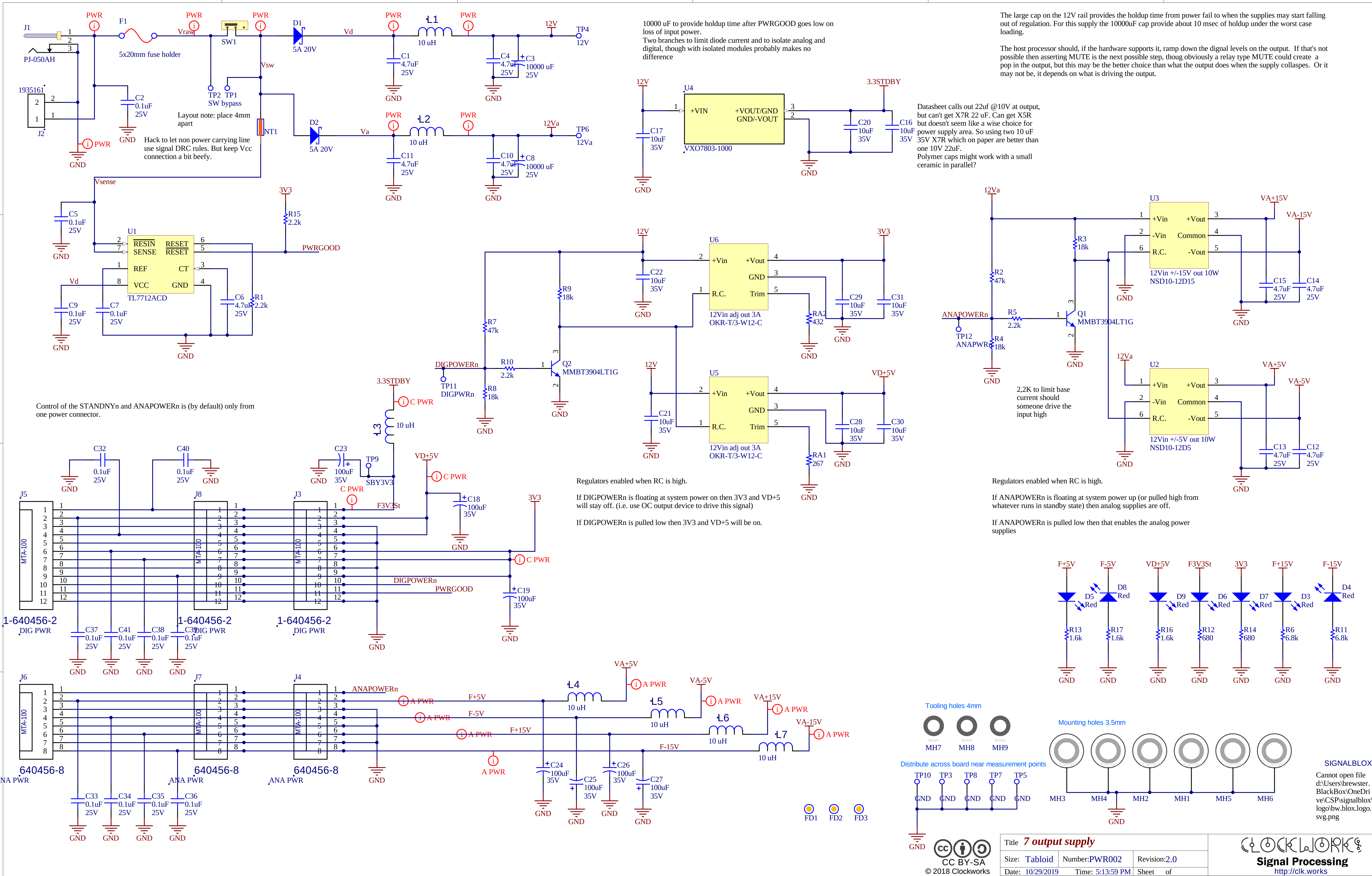

10000 uF to provide holdup time after PWRGOOD goes low on loss of input power.
Two branches to limit diode current and to isolate analog and digital, though with isolated modules probably makes no difference
The large cap on the 12V rail provides the holdup time from power fail to when the supplies may start falling out of regulation. For this supply the 10000uF cap provide about 10 msec of holdup under the worst case loading.
The host processor should, if the hardware supports it, ramp down the dignal levels on the output. If that's not possible then asserting MUTE is the next possible step, thoug obviously a relay type MUTE could create a pop in the output, but this may be the better choice than what the output does when the supply collapses. Or it may not be, it depends on what is driving the output.
Datasheet calls out 22uf @10V at output, but can't get X7R 22 uF. Can get X5R but doesn't seem like a wise choice for power supply area. So using two 10 uF 35V X7R which on paper are better than one 10V 22uF.
Polymer caps might work with a small ceramic in parallel?
5x20mm fuse holder
SW bypass
Layout note: place 4mm apart
Hack to limit non power carrying line use signal DRC rules. But keep Vcc connection a bit beefy.
12Vin adj out 3A
OKR-T/3-W12-C
12Vin +/-15V out 10W
NSD10-12D15
12Vin +/-5V out 10W
NSD10-12D5
2,2K to limit base current should someone drive the input high
Control of the STANDNYn and ANAPOWERn is (by default) only from one power connector.
Regulators enabled when RC is high.
If DIGPOWERn is floating at system power on then 3V3 and VD+5 will stay off. (i.e. use OC output device to drive this signal)
If DIGPOWERn is pulled low then 3V3 and VD+5 will be on.
Regulators enabled when RC is high.
If ANAPOWERn is floating at system power up (or pulled high from whatever runs in standby state) then analog supplies are off.
If ANAPOWERn is pulled low then that enables the analog power supplies
Tooling holes 4mm
Mounting holes 3.5mm
Distribute across board near measurement points
SIGNALBLOX ®
Cannot open file d:\Users\brewster.BlackBox\OneDrive\CSP\signalblox\logo\bw.blox.logo.svg.png
CC BY-SA
© 2018 Clockworks Signal Processing LLC
Title 7 output supply
Size: Tabloid
Number:PWR002
Revision:2.0
Date: 10/29/2019
Time: 5:13:59 PM
Sheet of
File: PWR002.main.SchDoc
Signal Processing
http://clk.works