TECHNOTE 001
PWR001 POWER SUPPLY NOISE SENSITIVITY ANALYSIS

An investigation of performance of the

Rev 1 Clockworks supply with different primary supplies

Rev 2.0

5-Mar-2019

Signal Processing

http://clk.works/

Products covered:

PWR001 triple output supply module

CC002 single AnalogBlox module carrier

1. TABLE OF CONTENTS

1 INTRODUCTION

This report provides details on an investigation during the engineering validation of the Rev 1 design of the effect of primary supply choice on the Clockworks PWR001 triple output module. There are two related reports that may be of interest to users of the PWR001 modules:

- TN002: Power sequencing. Investigates the hold up times of the PWR001 supply relative to the power good signal. This is important for controlling a system to minimize audio artifacts due to power cycling.
- TN003: Power supply noise impact. This looks at the impact of the PWR001 noise on a simple op-amp buffer circuit to see if there are issues beyond what the PSRR would suggest.

This report is focused on the +/- 15V output noise as that is of concern for use in sensitive analog stages of a SignalBlox system. It is desired that systems can support dynamic ranges in excess of 120 dB; doing so requires that noise sources be minimized across all aspects of the system.

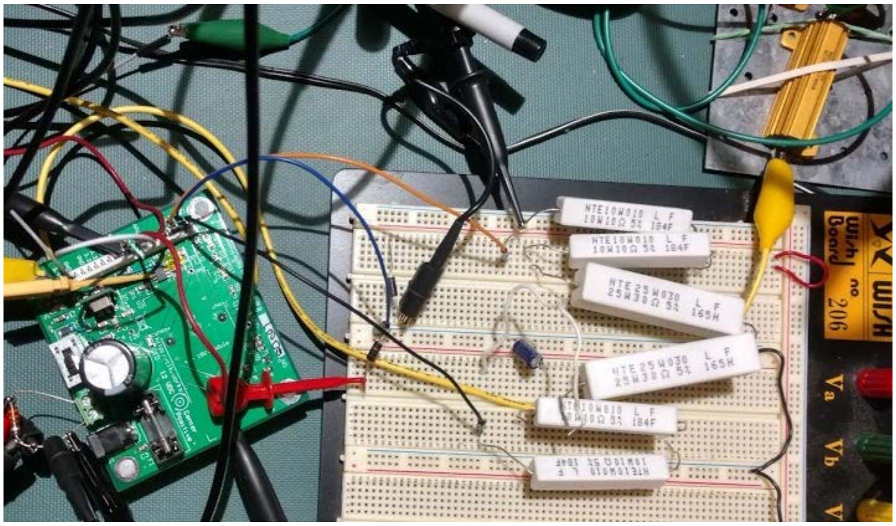


Figure 1 Test system components for measuring noise

While the test system looks ugly, the measurements are primarily concerned with noise in the audio band[1] and the layout/wiring is generally not critical.[2] Measurements of noise up to 20 MHz are made in

[1] For the purposes of these measurements audio band is defined as 44 kHz bandwidth, which is in part derived from the common use of 96 kHz sample rates when recording, and in part from the available bandwidth settings on the analyzed. The measurements are non weighted.
[2] If anything the horrible wiring and ground loops represents what a bad system design might look like, and things should still work.

the spectrum plots, but many of those peaks are most likely due to external interference; for example a local FM broadcast tower around 100 MHz is easily picked up by the system.

1.1 TESTED DEVICE

1.1.1 POWER MODULE

Clockworks triple output supply model PWR001, SN # E0001.

ECOs:

- Meanwell PowerModule ECO (footprint flipped, module mounts to back)
- 3.3V GND pin connection (pad isn't connected to ground in rev 1)
- Local +12V to TL7712 VCC pin (was wired to input 12V in rev 1)

ANAPOWERn line grounded so analog output will turn on when power applied.

These measurements are made on a prototype (rev 1.0) PCB. Some changes are expected in the production revision that would lower noise below the levels reported here.

1.1.2 PRIMARY SUPPLY

These sources were used for providing 12V to the DUT.

- MASTECH HY3005F-3 bench supply
- CUI SMI18-12
- Meanwell GST18U12-PiJ
- Meanwell GST60A12-P1J

1.2 TEST EQUIPMENT

Avermetrics Averlab generator/analyzer Version 2.1.1 B20-CL1253

Siglent SDS1204X-E oscilloscope Rev 8.1.6.1.24R2 software

To prevent saturation of the Averlab input a 2.2 uF film capacitor was place in series with its input. A 1 kOhm resistor to ground was also connected to lower the impedance for potential external sources; given the system is measuring a power supply with very low impedance the effects of the capacitor and resistor are inconsequential to the supply operation.

2 SUMMARY

- The primary supplies show a wide variation in ripple level and the frequency content of the ripple. All may be of concern if they were directly powering analog circuitry.

- The Meanwell module used for the +/-15V supplies are immune from the effects of the noise from the primary 12V supply in the audio band.
  - Noise in 44 kHz bandwidth measured -85 dBV.
- Outside of the audio band, one of the supplies (the Meanwell 60W supply) did create increases noise below 2 MHz.
  - It results in a 1 dB higher noise floor at the +/-15V output.
- One primary supply, the Meanwell 18W model, would continuously cycle through an apparent overcurrent shutdown, even though the load (1.3 amps) was below its 1.5 amp rating.
  - 25W class (2 amps @ 12V) supplies will be recommended to avoid possible issues in the future.
  - This is probably from the 10,000 uF capacitor, though it was observed that they cap remains partially charged (to around 3V) and the Meanwell supply still shuts down.
- The switching noise from the +/15V Meanwell supply, while well outside of the audio band, is significant and could generate IM products with other sources that would land in the audio band.
  - An LC filter was added and it makes a good reduction in the noise
  - This will be incorporated in to the Rev 2 design
- The 3.3V regulator, with light load of a few mA, switches at < 30 kHz
  - At 40 mA load the switching frequency is around 80 kHz
  - The same LC filter proposed for the +/- 15 lines significantly lowers the wide band and switching noise from the 3.3V supply and will be added to Rev 2
  - User need to be aware that a lightly loaded 3.3V may be an issue for noise.
- There's significant switching noise showing up on the 12V input line,[3] and with multiple regulators beat frequencies could also originate from there. The Rev 2 design will add a filter there for each regulator to reduce that noise as a potential source.

3 RESIDUAL NOISE IN SETUP

A nearby FM transmitter at 99.5 MHz is strong enough to find it's way in to any unshielded area on the bench. The scope is run with 20 MHz bandwidth for these tests; given the local filtering in the SignalBlox carriers and modules noise above those frequencies would most likely be radiated and not conducted.

The FFT axis in the scope captures is in dBV RMS. Note that you can not convert the broadband noise from that measurement in to a RMS value directly.

[3] Despite the low ESR of the big holdup cap,

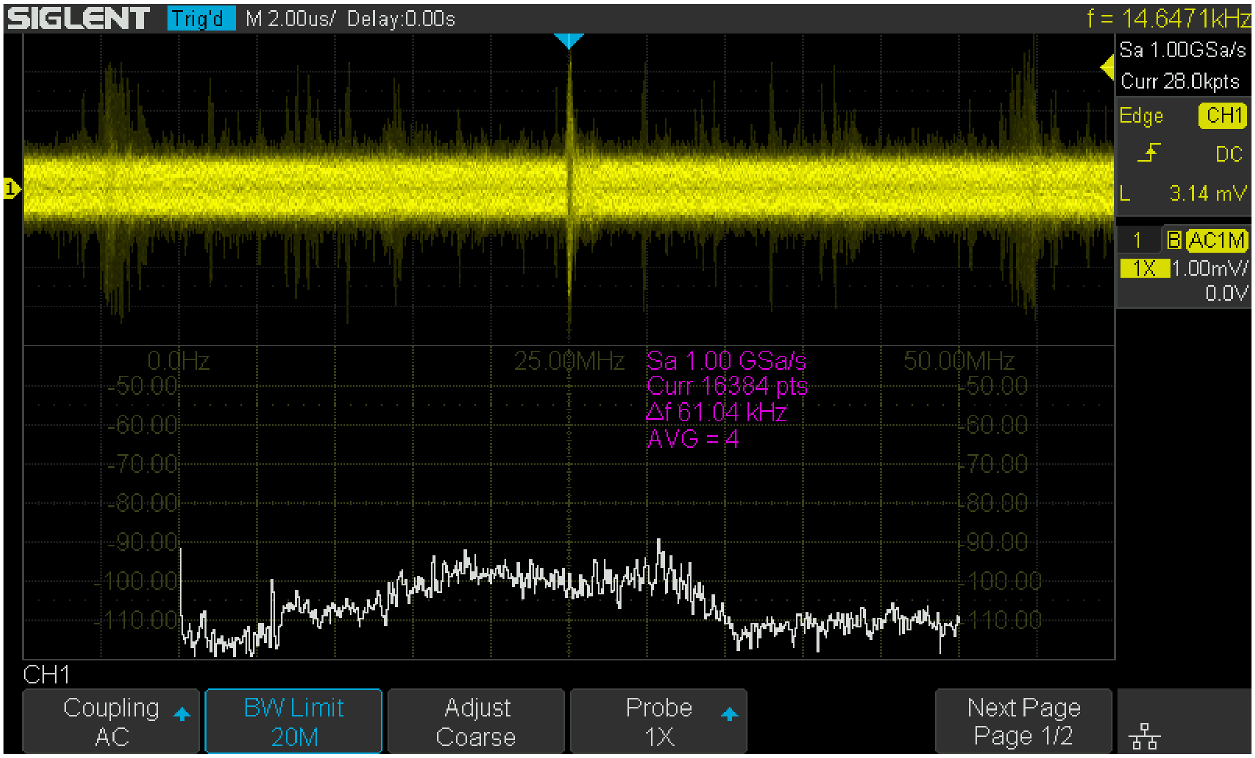


Figure 2 Measurement with 15 ohm resistor across scope probe.

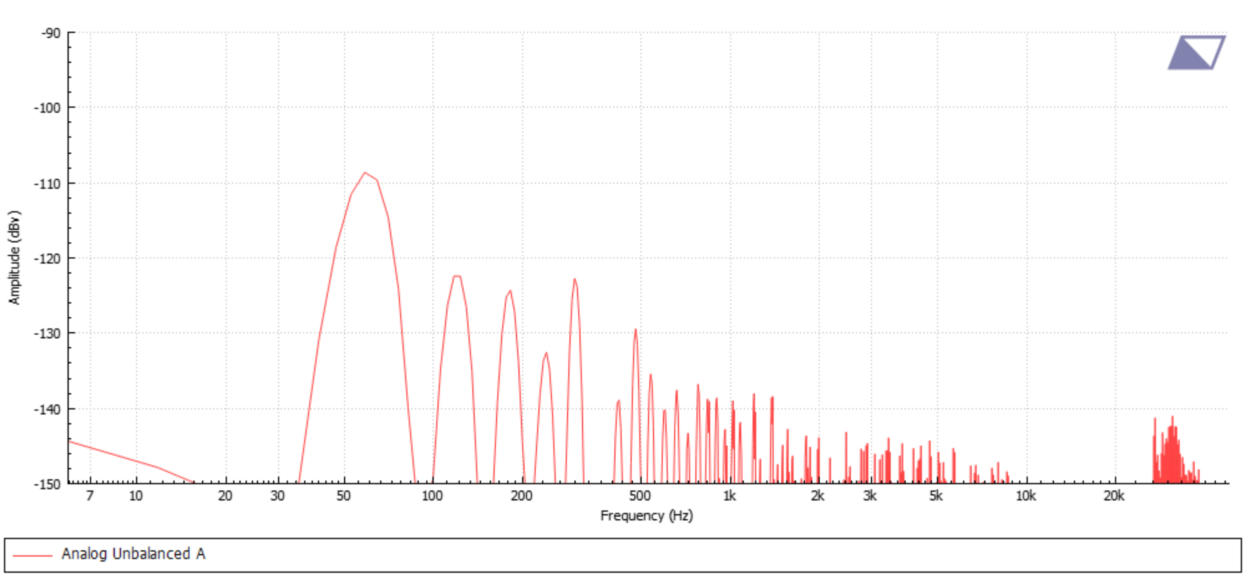


Figure 3 Audio band measurement with system off (16K PT FFT)[4]

[4] Unless noted otherwise the Averlab unit is set to 16K points and 4 averages unless noted otherwise. I defaults to a Rife-Vincent window, which is a form of cosine window.

The -110 dBv peak at 60 Hz corresponds to about 3 uV RMS. The exposed wiring of the test setup and potential for ground loops leads to these rather high background levels, however relative to the supply noise measurements these are inconsequential.

The measured noise level (44 kHz BW) is -107 dBv.

Both +15 and -15 V supplies measured the same in the audio band so only the +15V results are presented here.

4 12V SUPPLIES NOISE MEASUREMENT

Three different line supplies were used for initial testing to see if they made an impact on the noise from the analog output.

After measuring just the noise of the input supplies the output of the PWR002 module is measured to see if it's affected by the source supply in this configuration.

The plots include a scope trace and a spectrum of the captured signal.

For comparison here is a capture of a MASTECH HY3005-F bench supply.

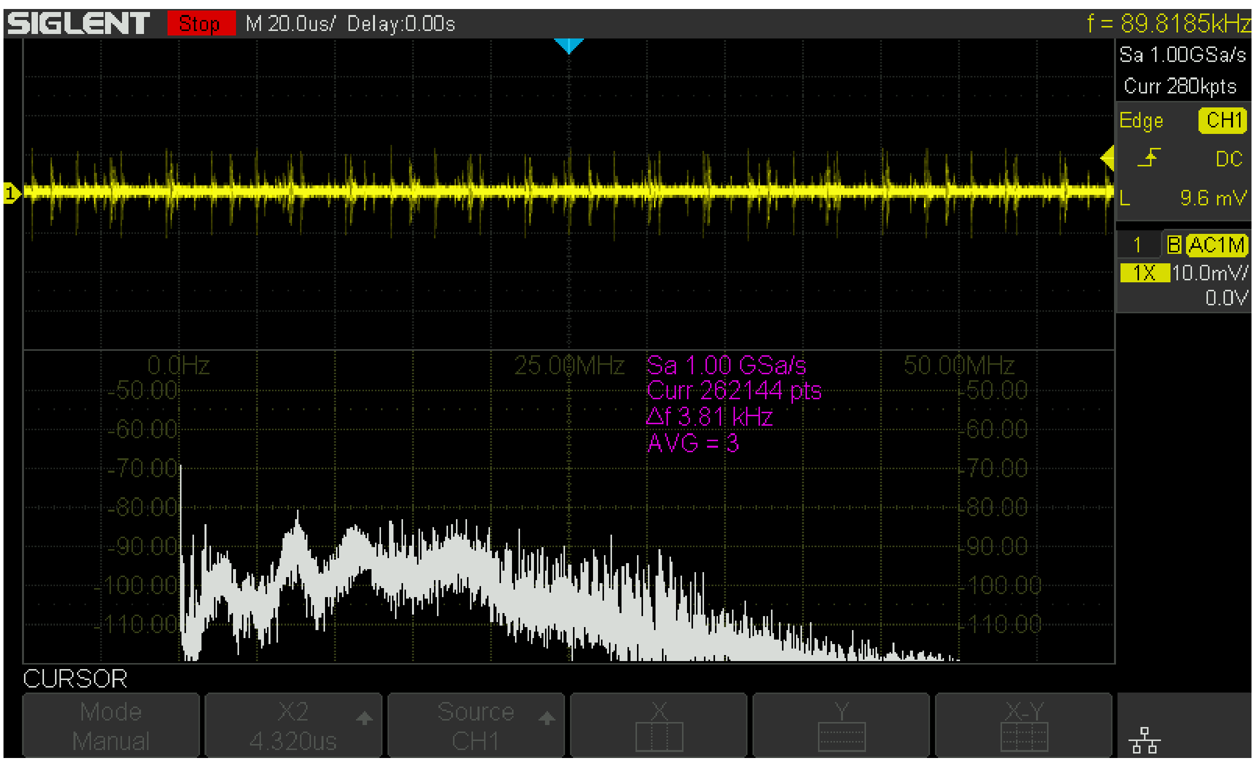


Figure 4 Bench supply with 75 ohm load (about 2W)

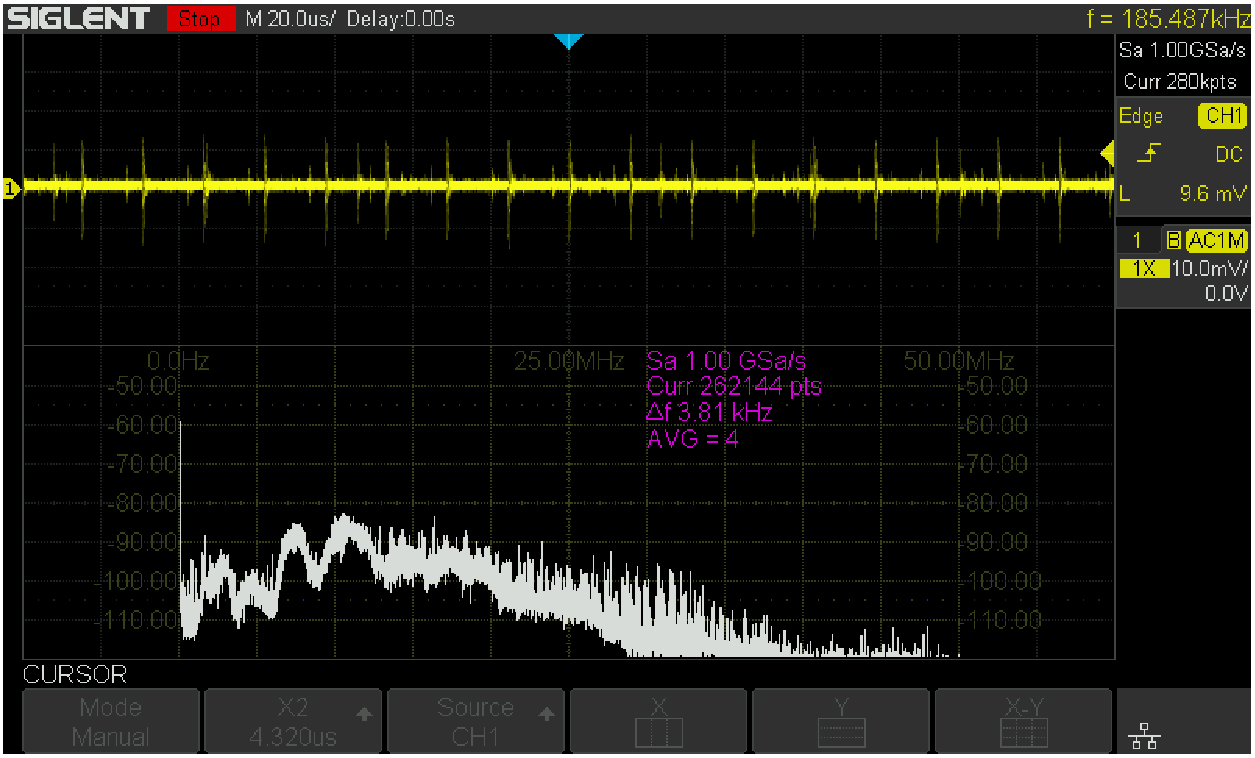


Figure 5 bench supply with 4 ohm (approx. 36W) load

4.1 CUI SMI18-12 12V 1.6A SUPPLY

Measured with load resistance of 75 ohms (160 mA), about 2 W. The large ripples are about 20 mV in size.

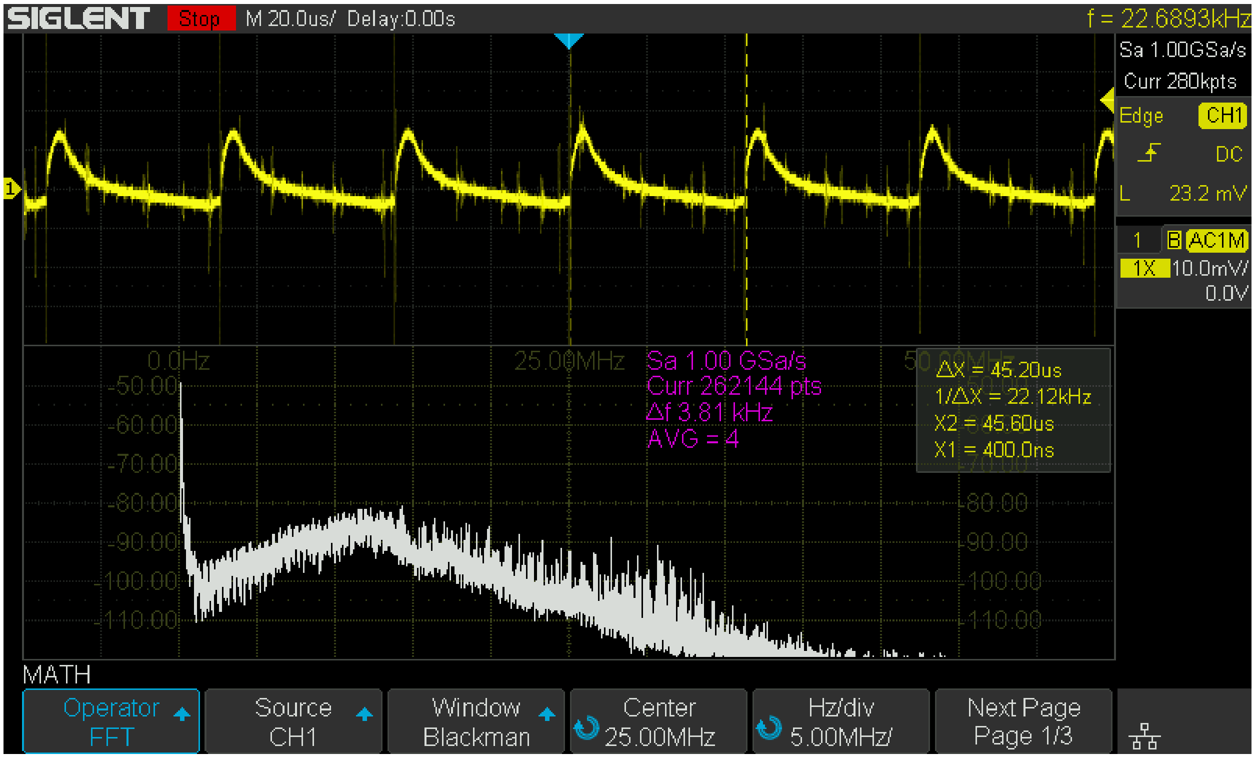


Figure 6 CUI 18W with 75 ohm load (about 2W)

4.2 MEANWELL GST18U12-P1J 12V 1.5A SUPPLY

Depending on the connected load, this supply would sometimes fail to remain powered up; instead it entered in to an overcurrent shutdown that repeatedly cycled every few seconds. For the purposes of the measurements this was avoided by powering the system and then connecting loads.

However this supply can not be used reliably under normal operation conditions.

The large ripples are about 15 mV in size.

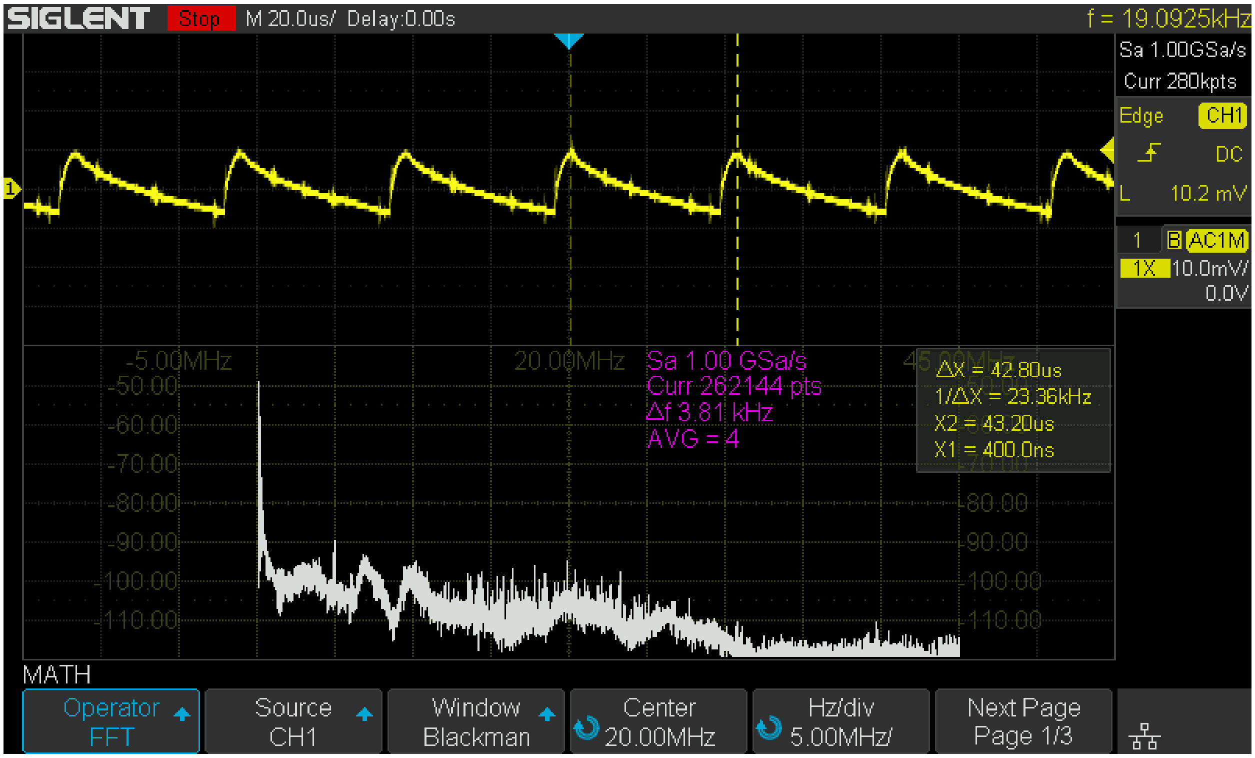


Figure 7 Meanwell 18W with 75 ohm load (about 2W)

4.3 MEANWELL GST60A12-P1J 12V 5A SUPPLY

Note the changed vertical and horizontal scales that were needed to capture this supply. It was captured with three different loads to observe the effect on noise. This supply produces a lot of noise that could fall within the audio band.

The low frequency ripple is approximately 50 mV, but the large spikes are over 200 mV.

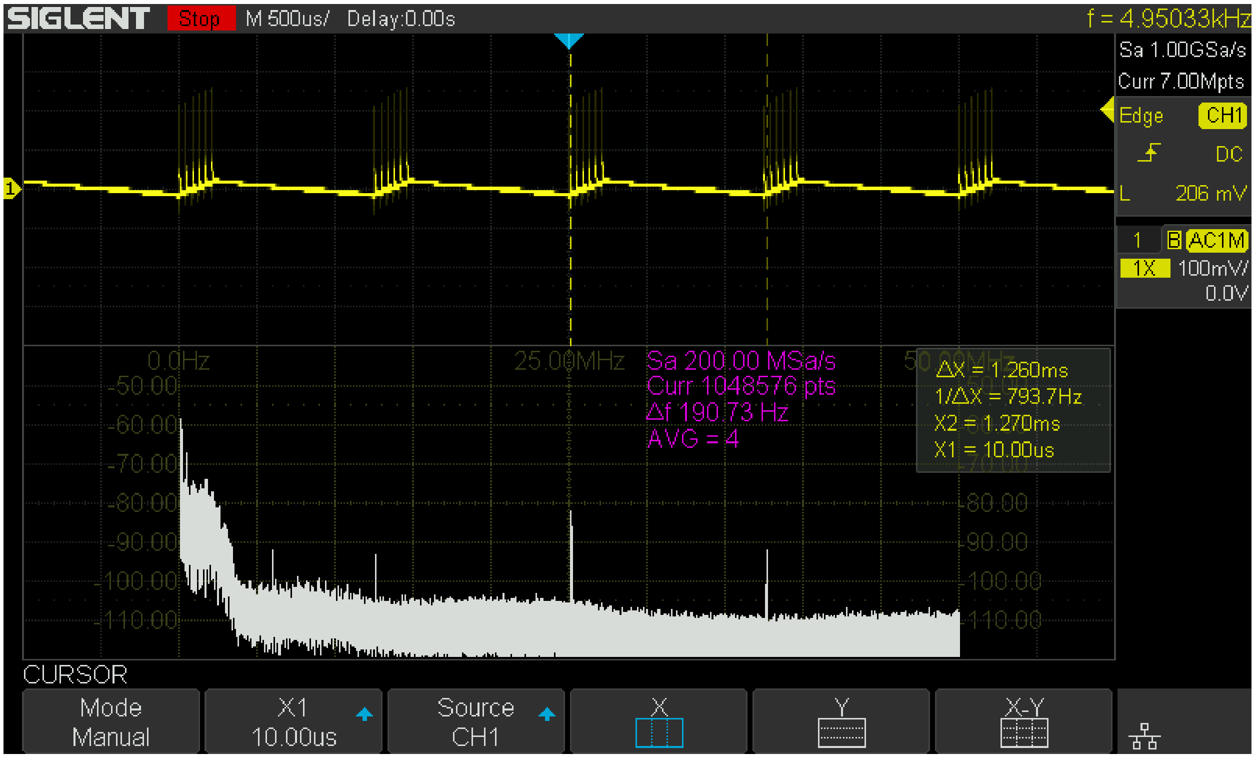


Figure 8 Meanwell 60W supply with 75 ohm (approx. 2W) load (500 usec/div)

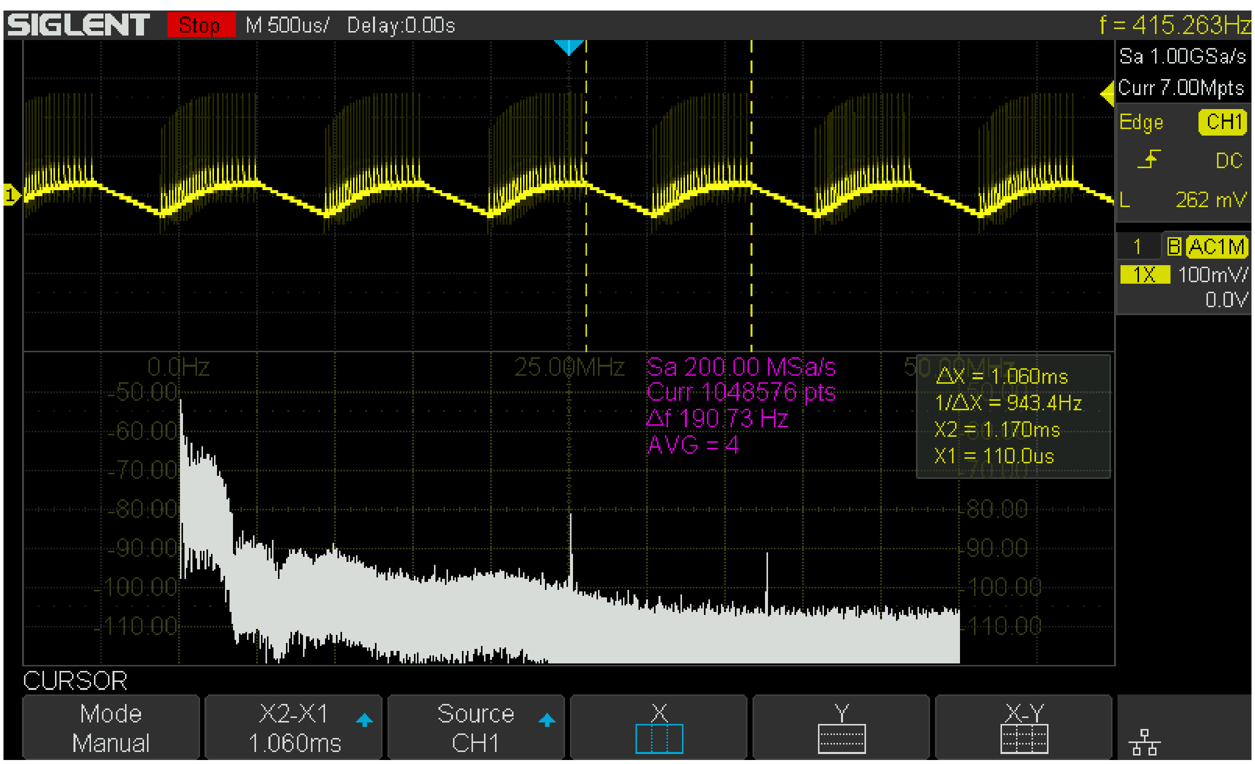


Figure 9 Meanwell 60W supply with 15 ohm (approx. 10W) load (500 usec/div)

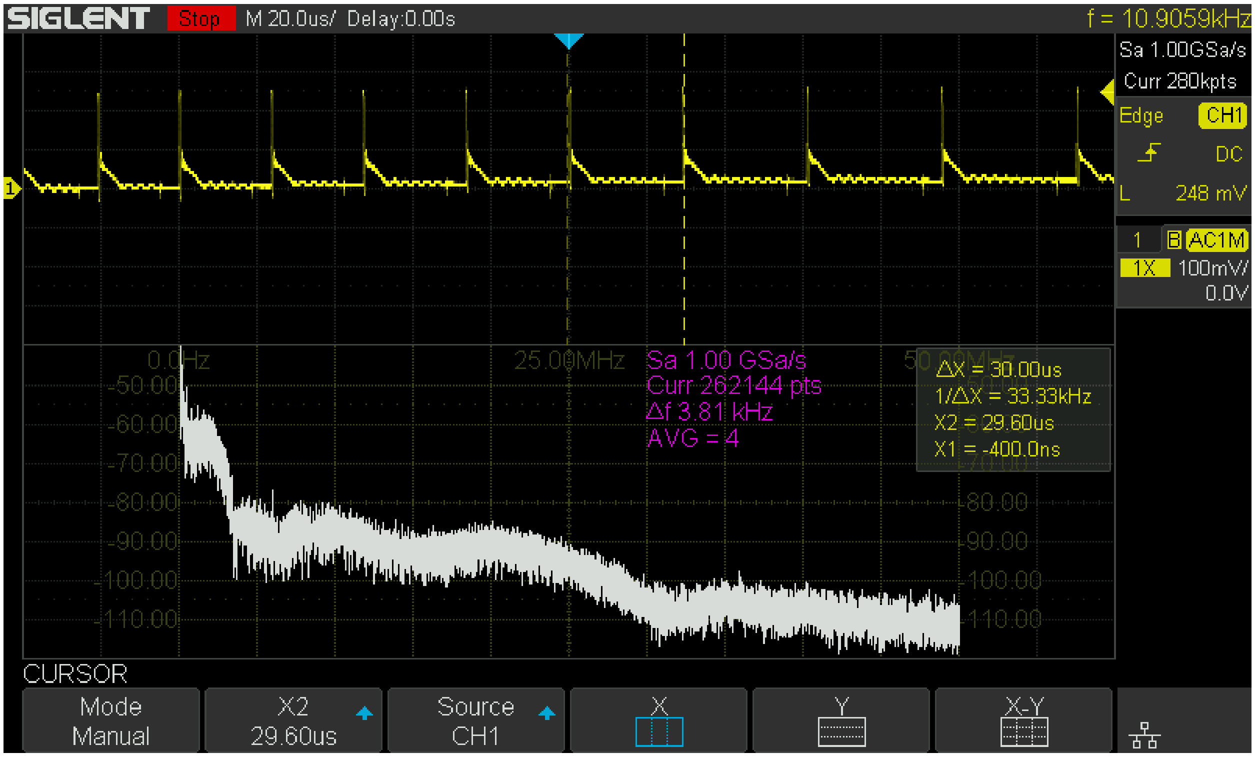


Figure 10 Meanwell 60W supply with 15 ohm (approx. 10W) load detail (20 usec/div)

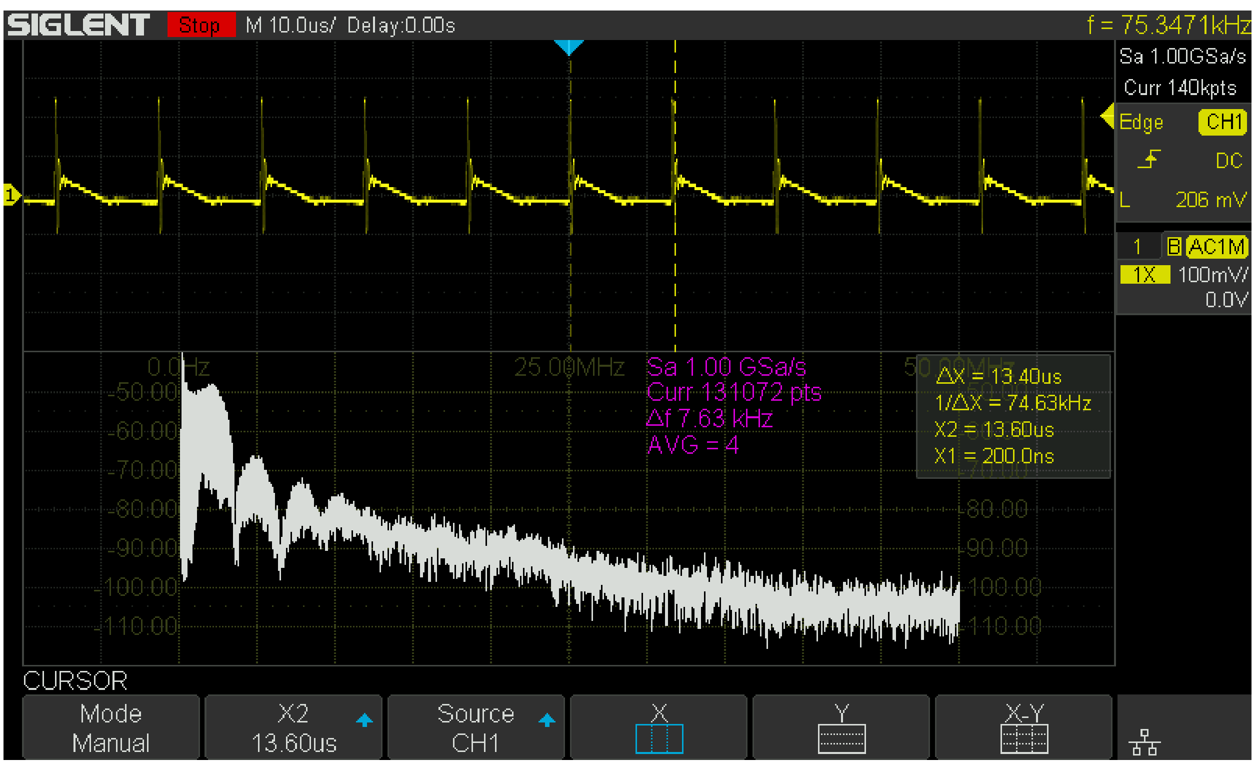


Figure 11 Meanwell 60W supply with 4 ohm (approx. 36W) load (20 usec/div)

5 PWR001 NOISE MEASUREMENT WITH DIFFERENT PRIMARY SUPPLIES

The PWR0001 was loaded with 8 ohms on the 3.3V out (0.4A, about 1.4W) to represent a typical load and possible contributions to noise.

The +/-15V outputs were loaded with 75 ohms each (0.2A, about 3W). Channel 1 (Yellow) is on the +15V and channel 2 (Magenta) is on the -15V. The spectrum is from channel 1.

Channel 3 (Blue) was connected to the 12V input.

A baseline using the bench supply was made. 0.8A was being drawn (9.6W) with a load total of 7.4W, or about 77% efficiency.

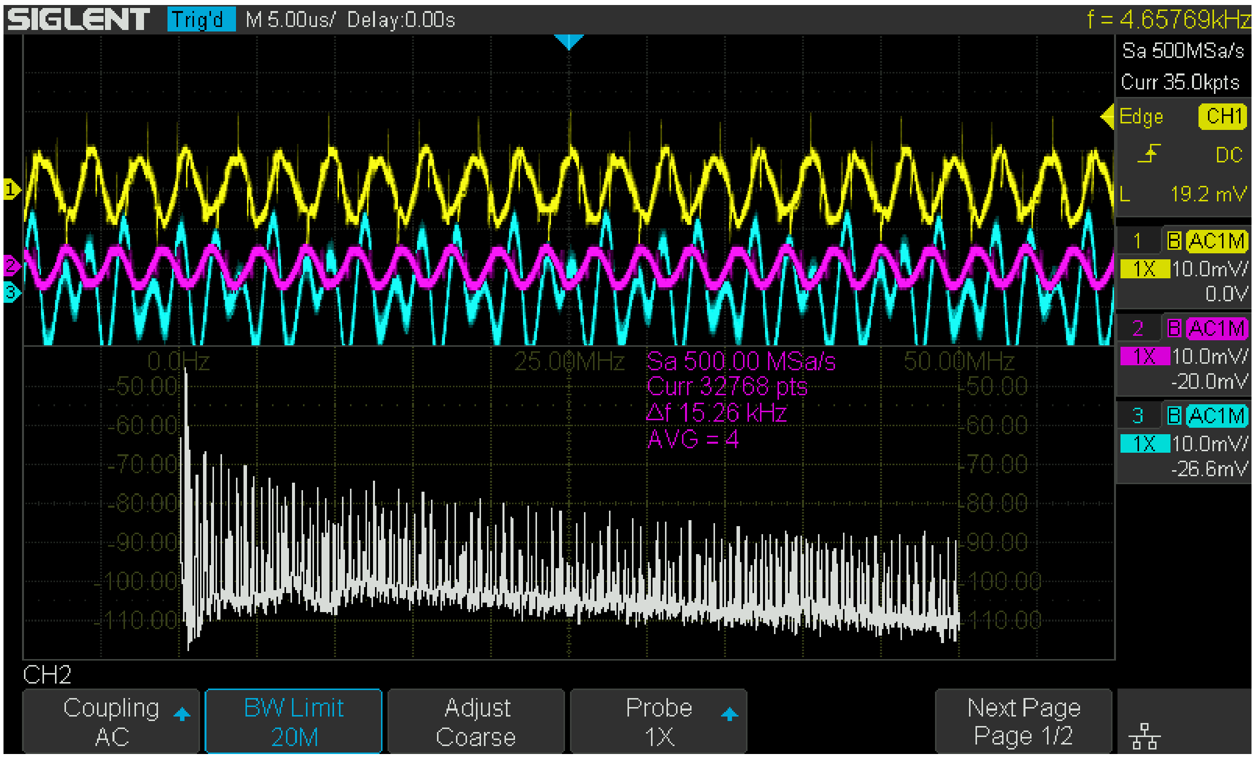


Figure 12 +15V (Yellow) -15V (Magenta) 75 ohm load with bench supply (Blue) as source.

As the -15V output was consistent it will not be shown in subsequent plots. Its ripple level is observed to be about half the positive output.

The small spikes may represent a ground loop problem in the test setup versus actual output noise.

The Meanwell modules have a specified ripple of 75 mV PP so the 20 mV seen here is well within expectations.

Noise from the primary supply is dominated by the local PWR001's modules two switching frequencies, which are 350 kHz and 520 kHz for the Meanwell and CUI modules, respectively.

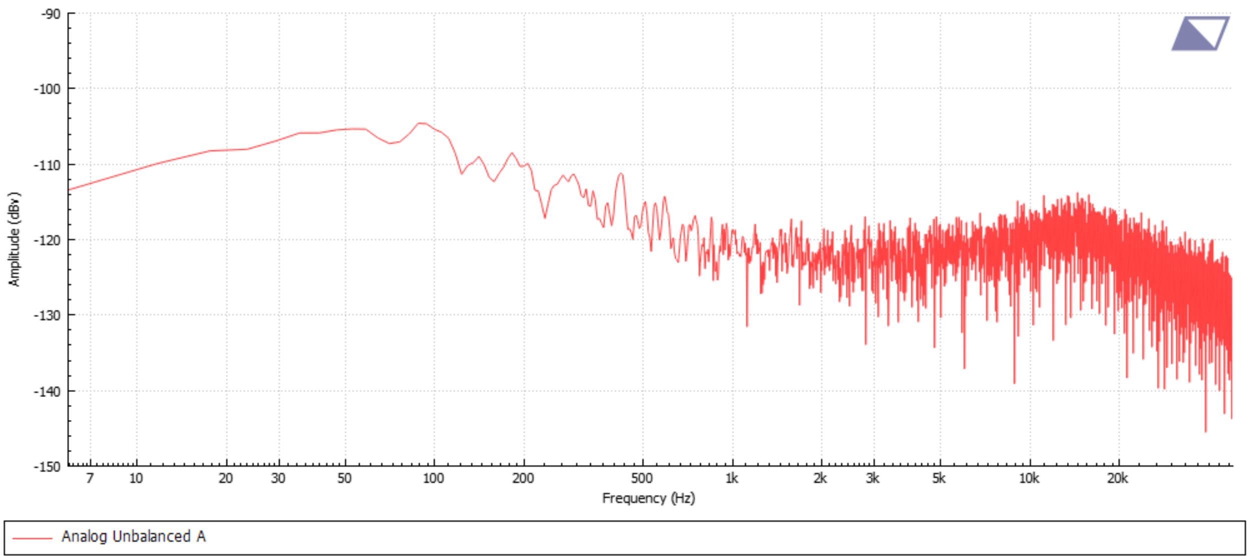


Figure 13 Audio bandwidth measurement with 75 ohm load on +15V. Bench supply. 16K PT FFT

The measured noise level is -85 dBv (44 kHz BW)

5.1 CUI SMI18-12 12V 1.6A SUPPLY

Though not obvious in the scope plot, additional high frequency noise was noticed. However this could be changed with moving ground wires around and therefor the suspicion is that it's a setup problem and not actual supply noise.

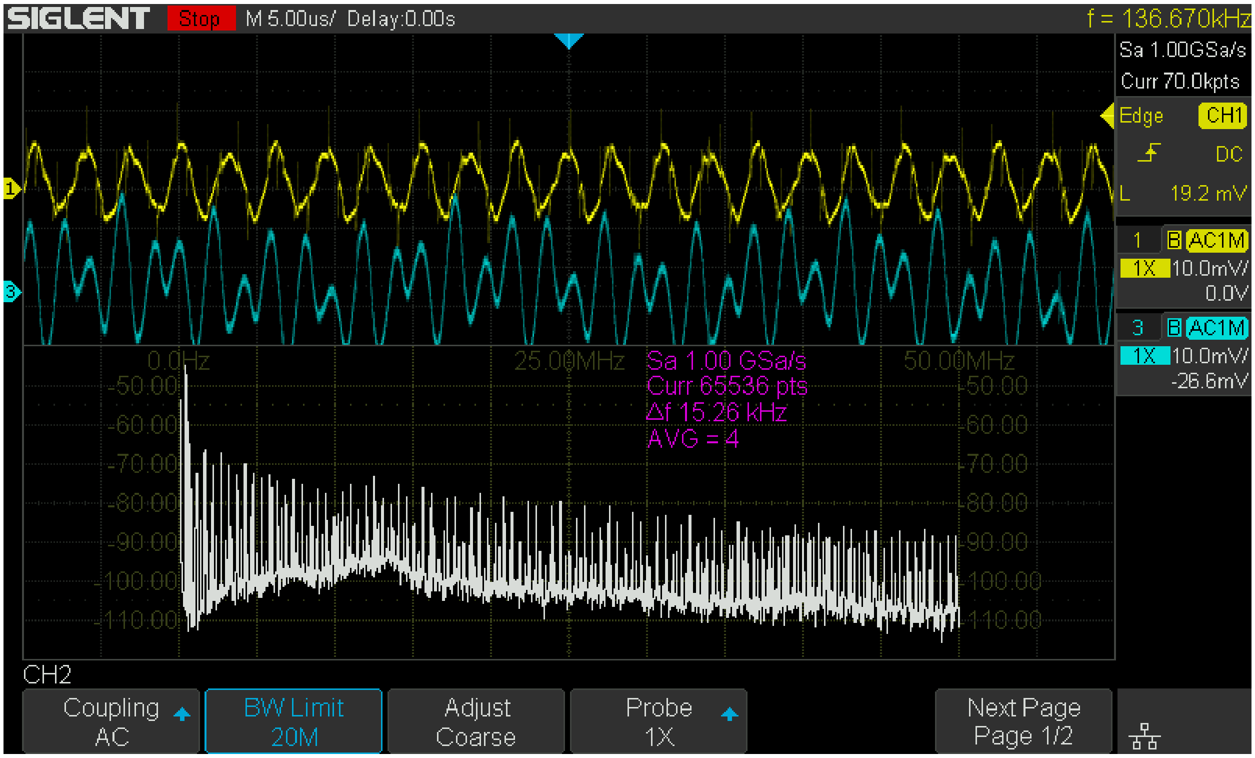


Figure 14 +15V (Yellow) 75 ohm load with CUI 18W supply (Blue) as source

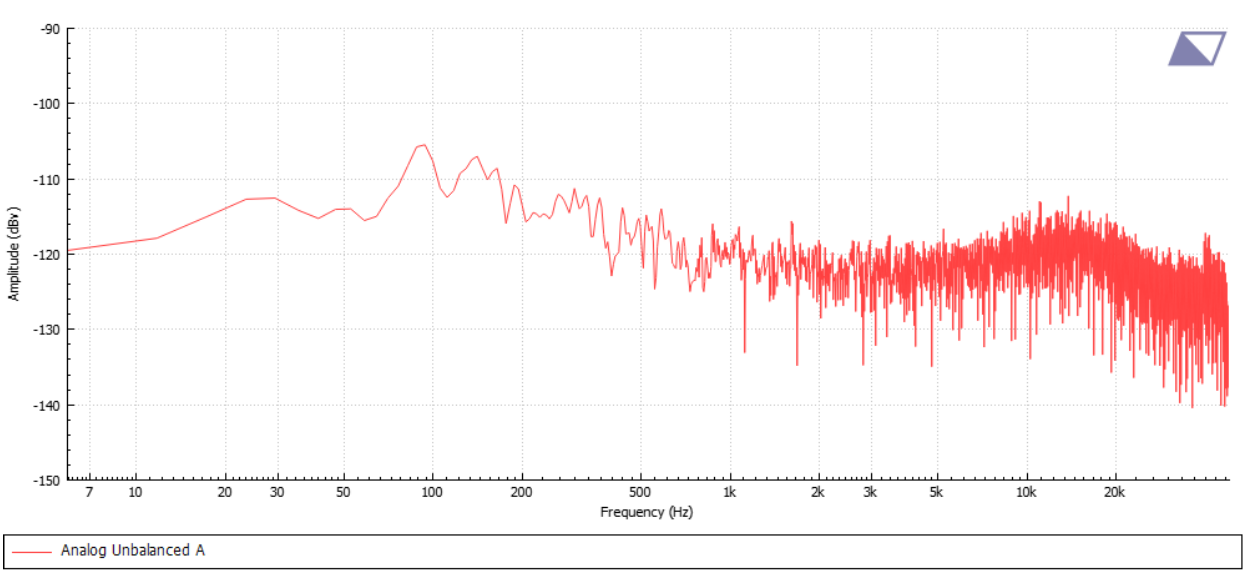


Figure 15 6 Audio bandwidth measurement with 75 ohm load on +15V. CUI supply. 16K PT FFT

The measured noise level is -85 dBv (44 kHz BW)

5.2 MEANWELL GST18U12-P1J 12V 1.5A SUPPLY

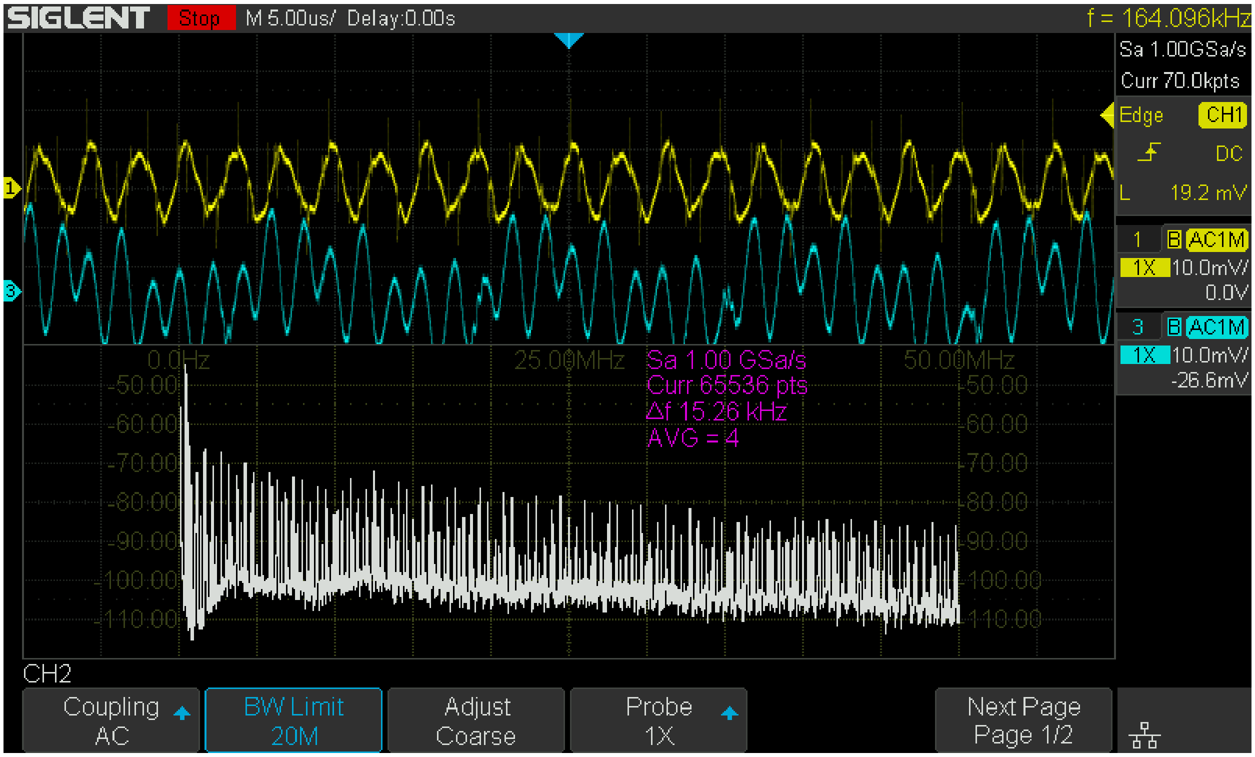


Figure 16 +15V (Yellow) 75 ohm load with Meanwell 18W supply (Blue) as source

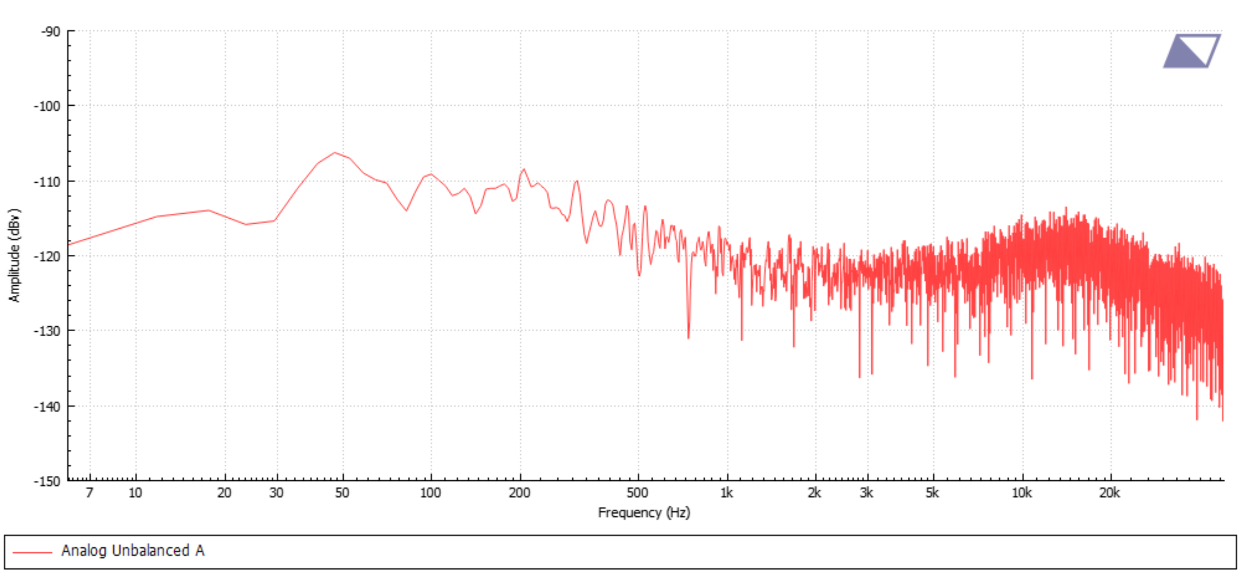


Figure 17 Audio bandwidth measurement with 75 ohm load on +15V. Meanwell 18W supply. 16K PT FFT

The measured noise level is -85 dBv (44 kHz BW)

5.3 MEANWELL GST60A12-P1J 12V 5A SUPPLY

While the high input noise is still present it does not appear on the 15V outputs other than an apparent bump in the noise floor around 2 MHz and a 1 dB increase in the 44 kHz bandwidth audio measurement.

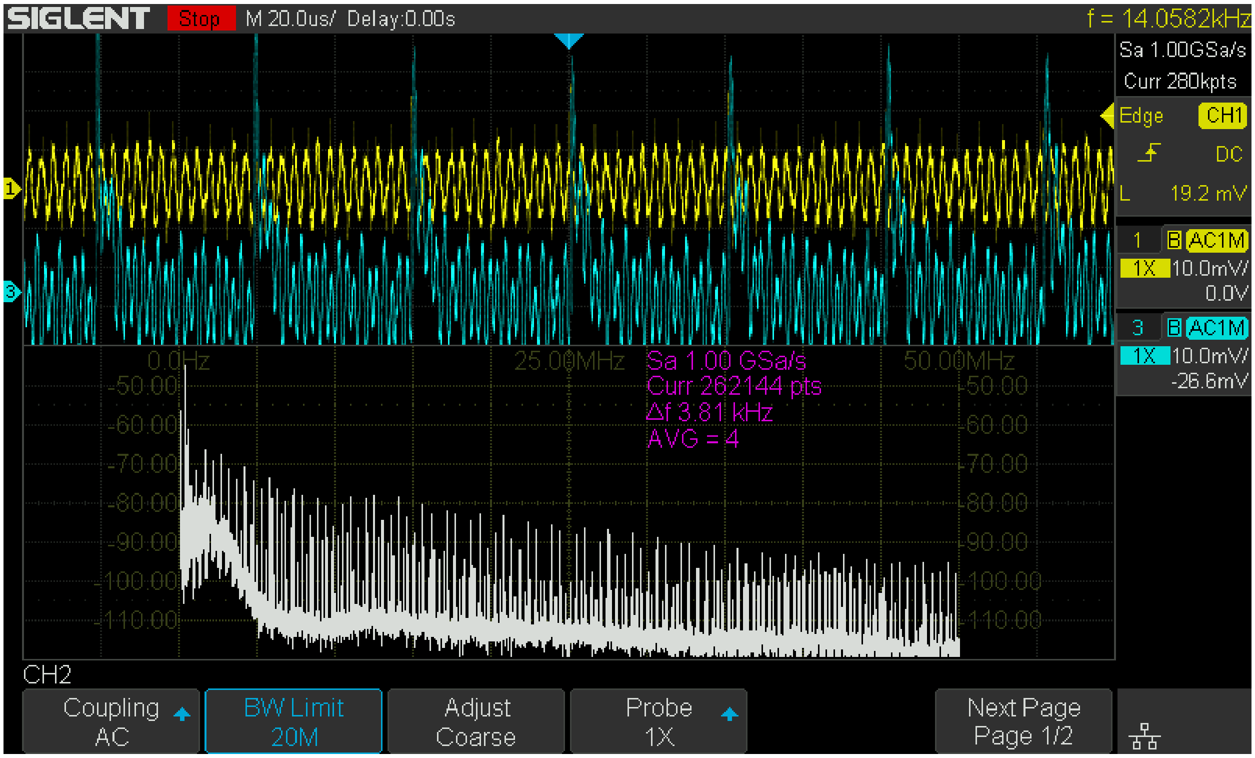


Figure 18 +15V (Yellow) 75 ohm load with Meanwell 60W supply (Blue) as source

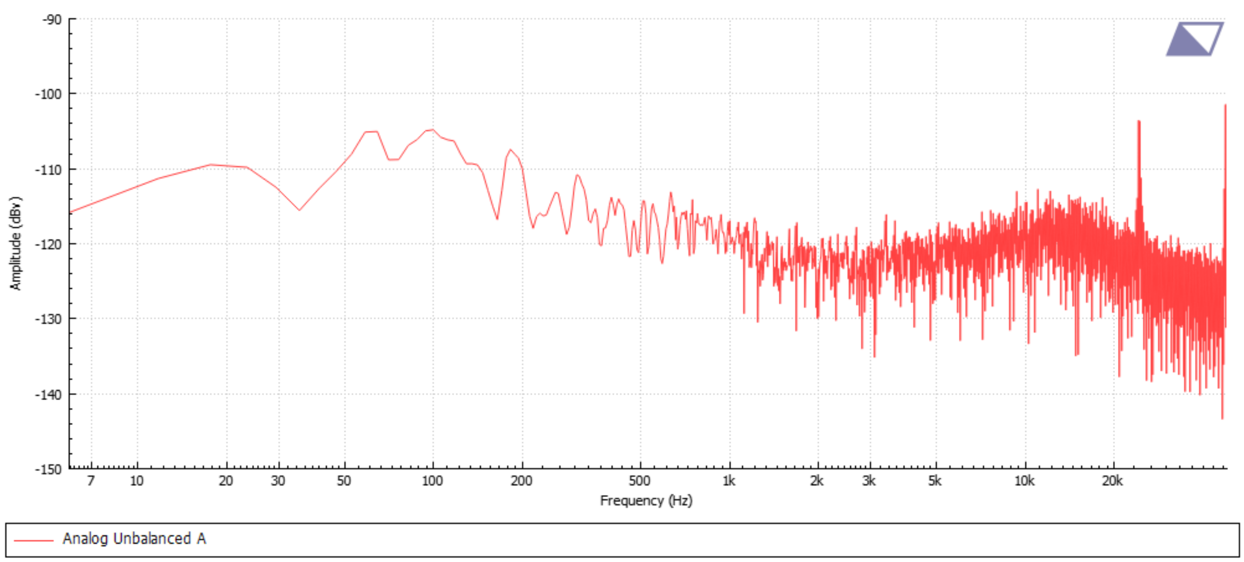


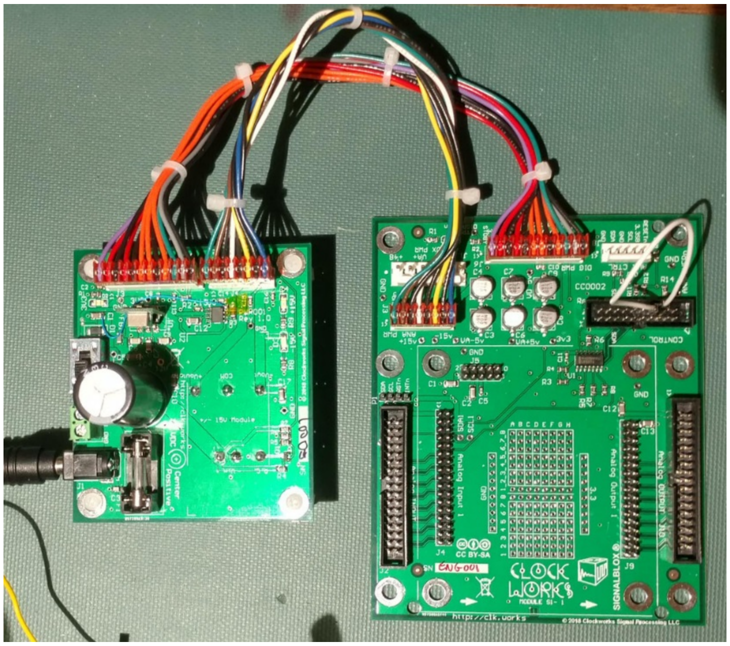
Figure 19 Audio bandwidth measurement with 75 ohm load on +15V. Meanwell 60W supply. 16K PT FFT

The measured noise level is -84 dBv (44 kHz BW)

6 MEASURED RIPPLE AT CC002

These tests measured the ripple as seen at a carrier module. The single module CC002 carrier was used with no AnalogBlox module connected. The probe test points on the CC002 were used. The jumper shown in the picture is to strap the ANALOGPWRn signal to ground to that the analog supplies will turn on.

The Meanwell 18W supply was used for testing, though as was previously noted it can have difficulty starting up correctly. In the cases tested in this section there was minimal load, so it is assumed that the cause of the overcurrent shutdown is the large in-rush current due to the large 10,000 uF hold-up capacitor.



6.1 15V

This carrier has 100uF on the +/- 15V rails. However this is not enough to reduce the ripple as 5.4 mV PP is measured at 325 kHz on the Rev 1 board. While this is out of the audio band it can cause problems with intermodulation products with other signals found in the system.[5]

Adding a 5 uH and 100 uF filter reduces the ripple to below 1 mV. (Fc = 7 kHz)

[5] The fuzz in the captures appears to be mostly from the FM broadcast pickup on the bench.

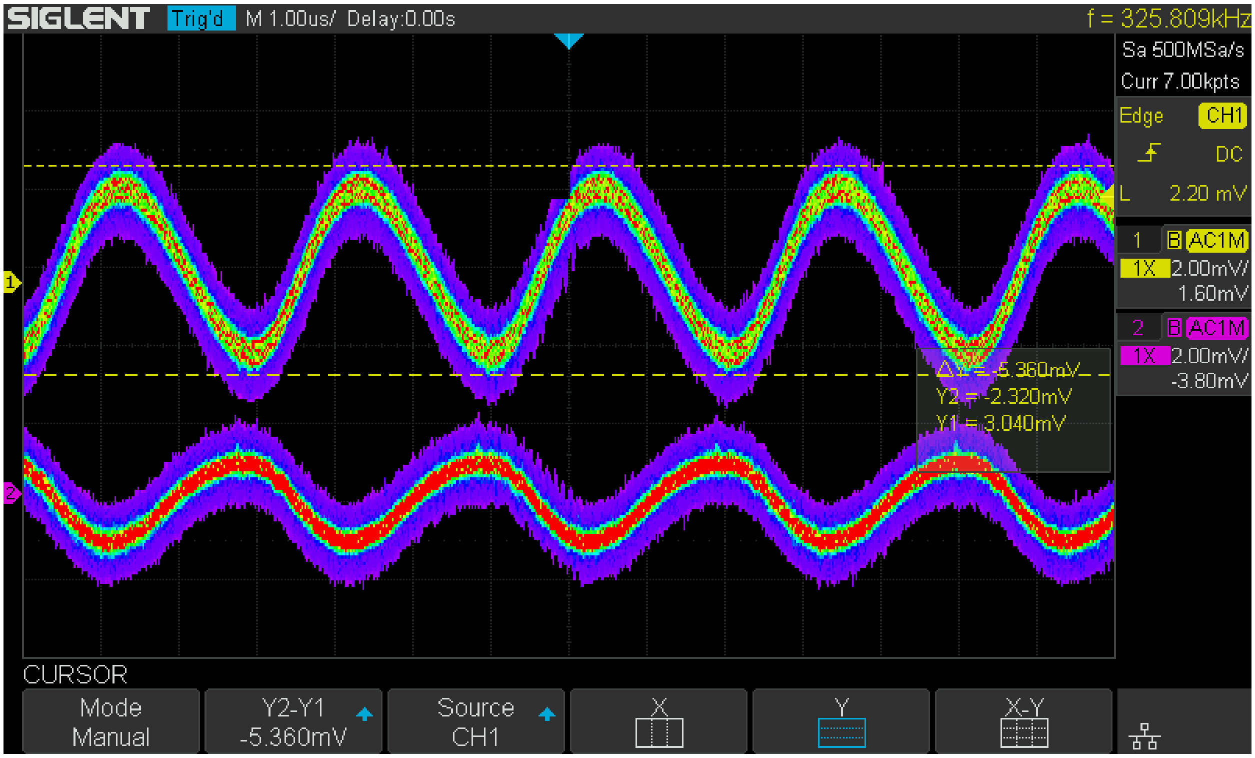


Figure 20 Ripple at CC002. +15 (Yellow, ch1), -15 (purple, ch 2). Color map, 5 sec persistence

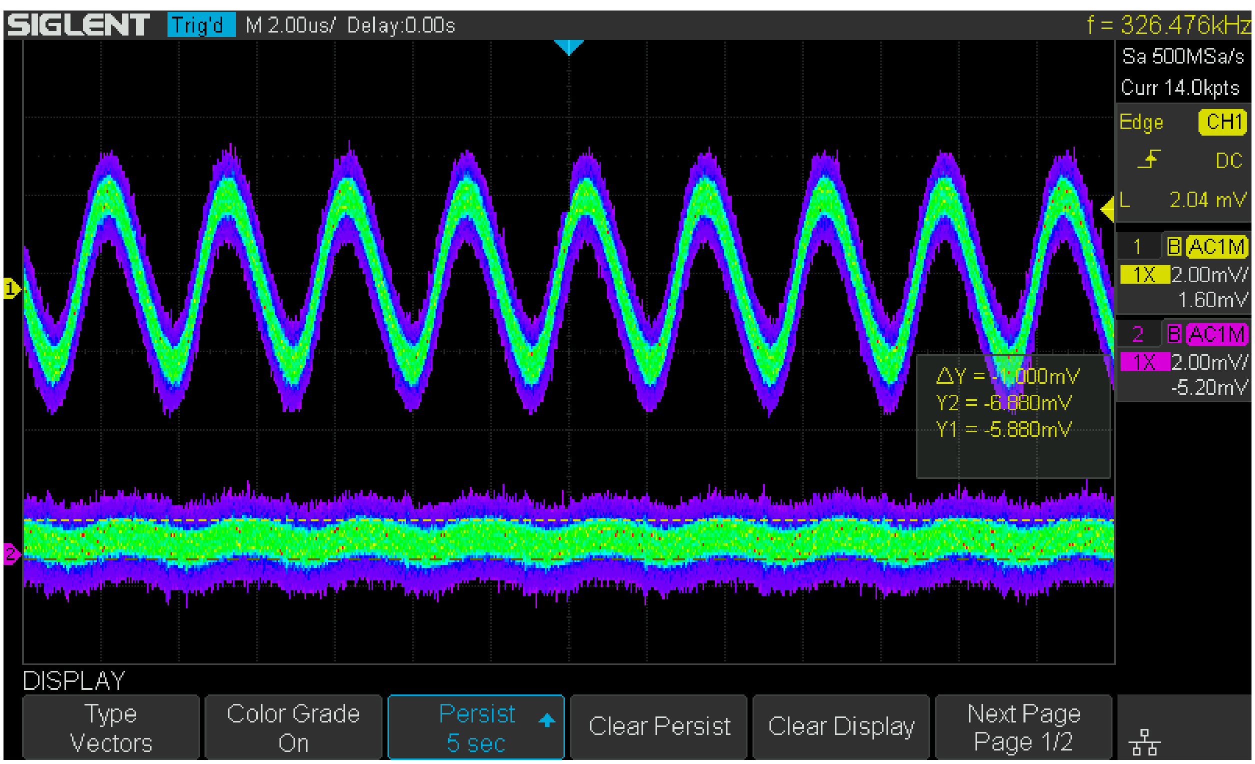


Figure 21 Ripple at CC002. +15 in (Yellow, ch1), filter out (purple, ch 2). Color map, 5 sec persistence

6.2 3.3V

While the focus was on the +/- 15V used for the analog circuitry, noise from the 3.3V supply can also find its way in to analog circuits. About 15 mV PP ripple is observed on the 3.3V measured at the CC002.

Adding the same filter as used for the +15 analysis reduces it to 5 mV PP.

These measurements and the next 4 plots were made with the 3.3V lightly loaded – only a few mA.

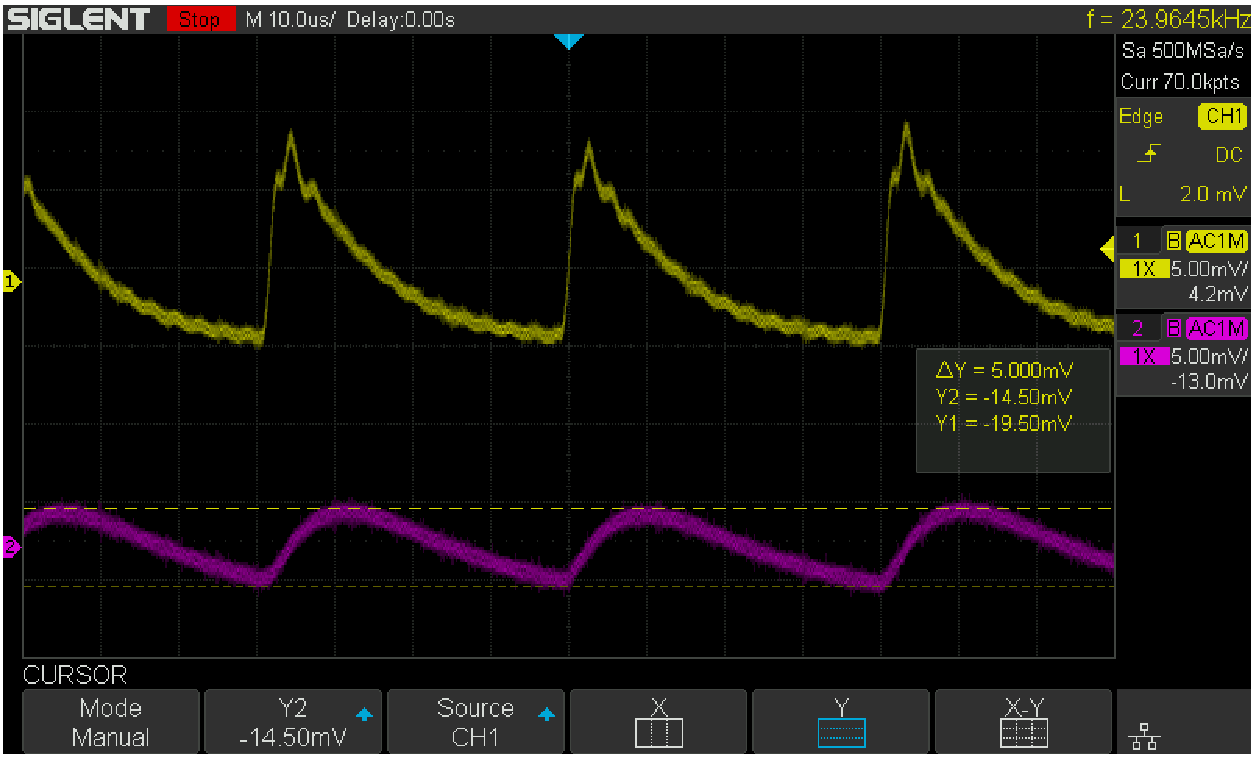


Figure 22 Ripple at CC002. +3.3 in (Yellow, ch1), filter out (purple, ch 2).

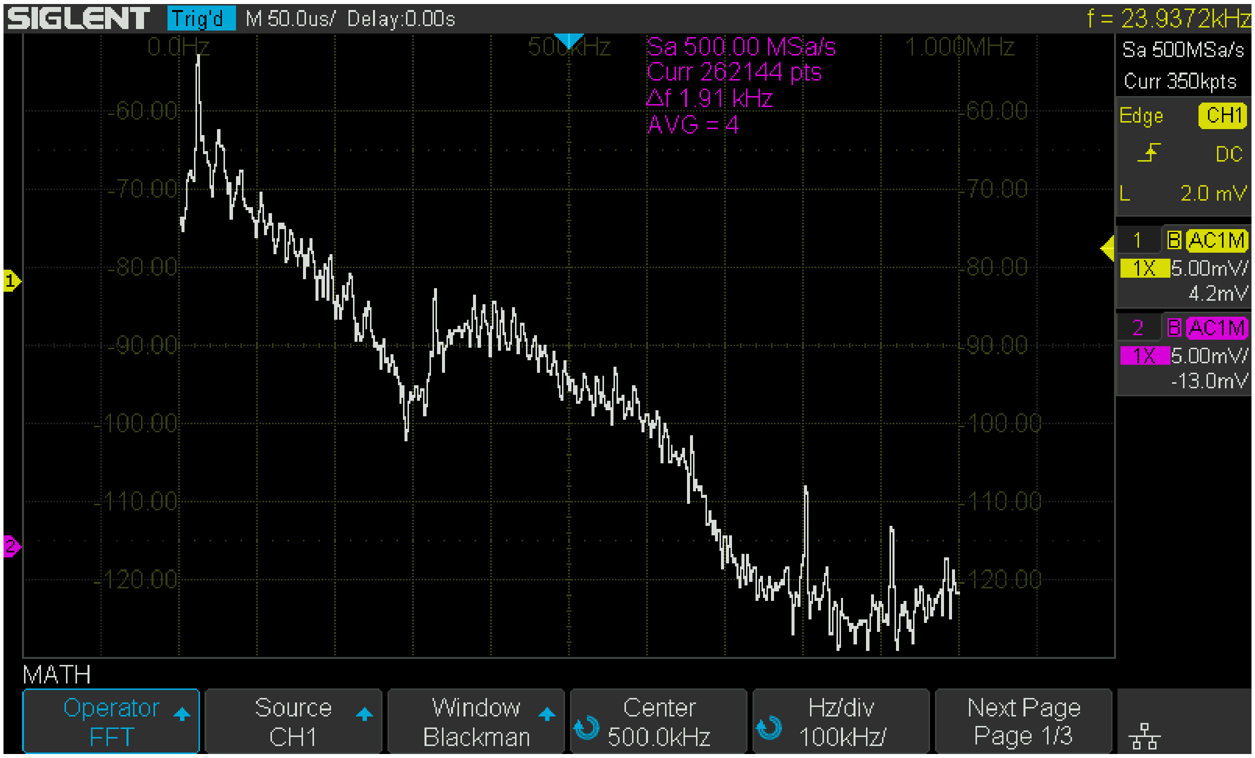


Figure 23 Spectrum of unloaded 3.3V supply, no filter

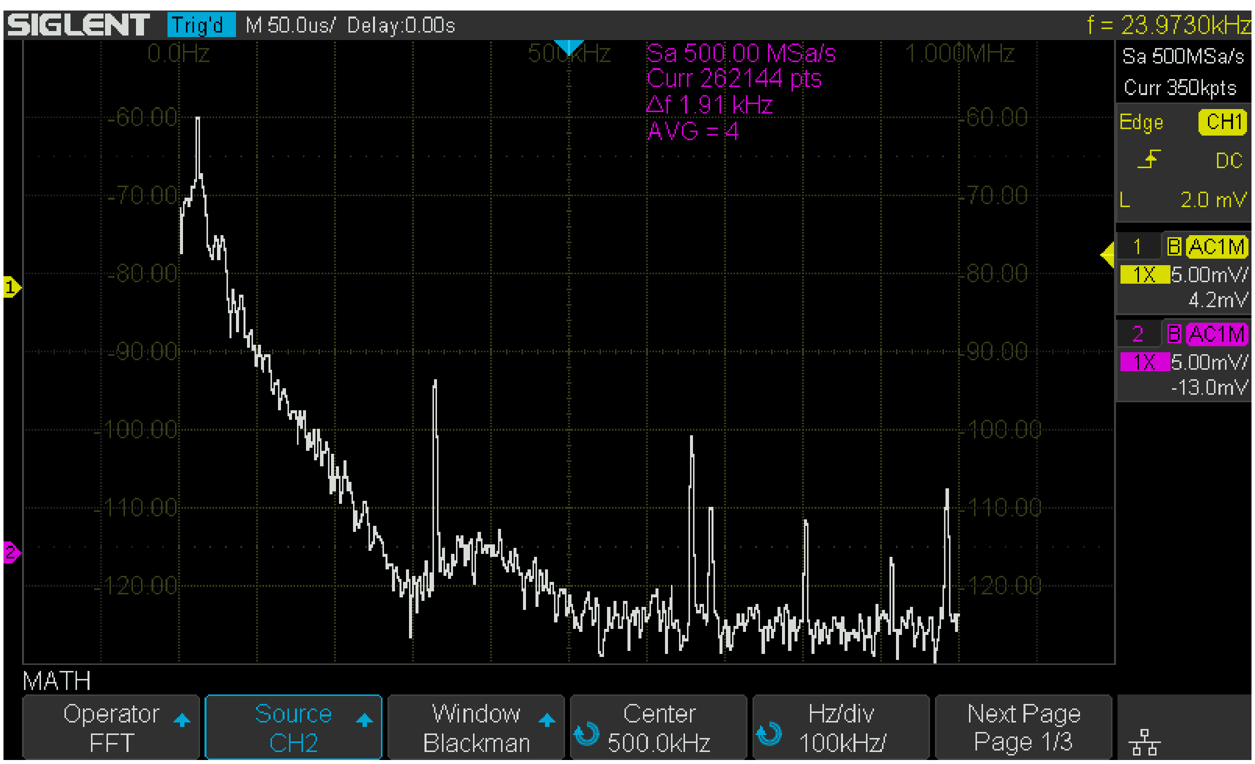


Figure 24 Spectrum of unloaded 3.3V supply, with filter

6.3 INCREASING LOAD ON THE 3.3V SUPPLY

With a 75 ohm load (44 mA) the switching frequency is up to 84 kHz and the ripple is reduced.

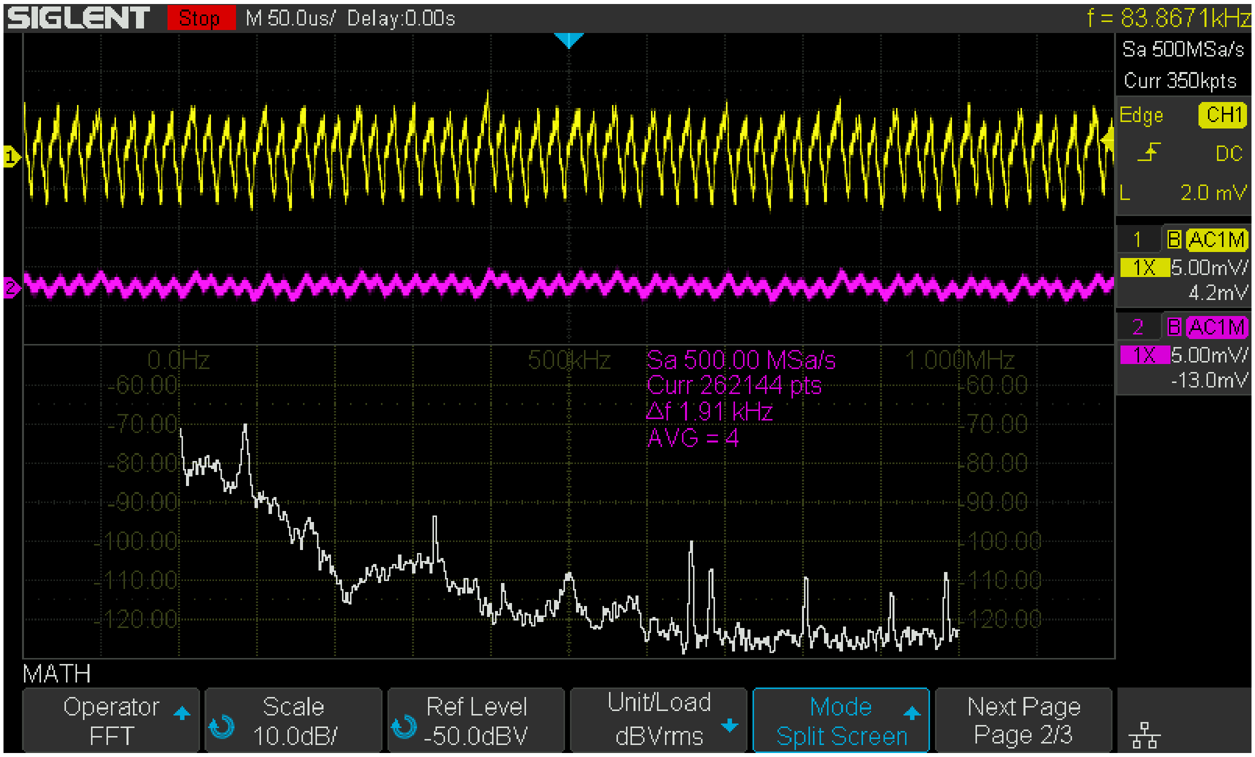


Figure 25 3.3V supply with 75 ohm load. Input (Yellow, ch 1), filter out (magenta ch2), filter out spectrum (white)

Increasing the load to 330 mA with a 10 ohm load shifts the frequency higher but also further reduces its magnitude at the board input. The filter then further reduces that to levels below the measurement setup.

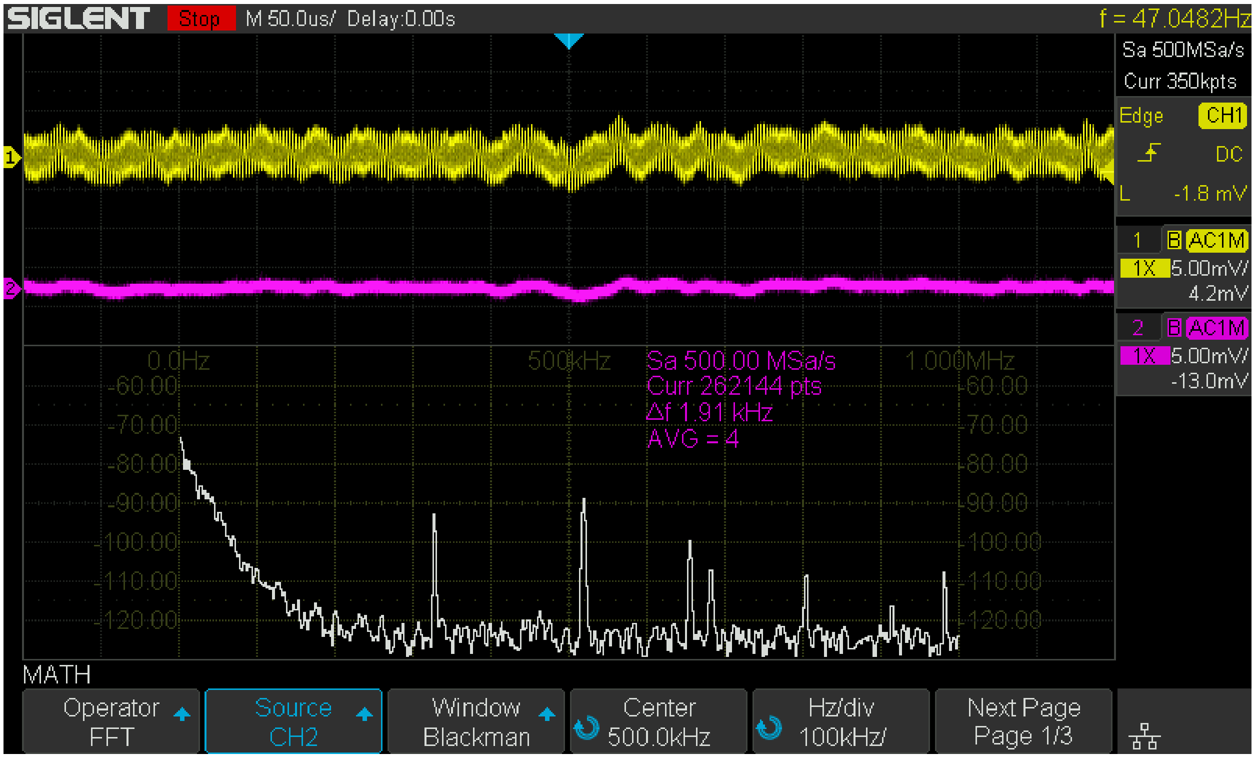


Figure 26 3.3V supply with 10 ohm load. Input (Yellow, ch 1), filter out (magenta ch2), filter out spectrum (white)