A Noise Meter Suitable for Sun & Moon Noise Type Measurements

By: VK3NX

Preface: In trying to track the moon on the higher microwave bands for EME operation it became very obvious to me early on, that with the beamwidths normally encountered, it was not enough to rely on the dish calibration to be sure one was pointing directly at the moon. With only a slight misalignment, I found that signals would be lost. So how to overcome this? One of the easiest ways is to track via moon noise and not solely rely on the dish mechanics and indicator system. Whilst this is not an article on automatic tracking of the moon, it describes a device that gives a visual aid to helping one keep the moon in the "bore-sight". As a by product it allows for very accurate measurements on sun, moon and "cold sky" / Ground measurements. Its usefulness is also to help evaluate receive system changes & modifications with real world analysis for any receiver system.

INITIAL THOUGHTS AND CONCEPTION:

The noise meter described below will find many uses in an experimenters' shack. LNA comparisons, antenna array performance and analysis of microwave feeds ….. the list is only limited by the imagination!

There are many things to consider when trying to measure noise. There are many ways to accomplish this. We can use the audio output of a receiver with a linear gain and NO AGC applied to do measurements or A / B comparisons. This works reasonably well for Sun Noise measurements and to a lesser extent for ground to cold sky measurements. But for evaluating moon noise this method failed miserably for me. After discussing this with Luis Cupido (CT1DMK) he showed me how integration mathematics is required to see that it will be almost impossible to see or measure accurately moon noise with a typical microwave EME system, such as mine, UNLESS the moon noise is several dB above the background noise. What is required is a "WIDEBAND" signal compared with the "narrow bandwidth" of the audio spectrum.
Most of my EME transverters use an IF of 144MHz and as such it was an easy choice to utilize this part of the spectrum to examine a wide bandwidth portion when looking at moon noise.

In issue 2 in 2000 of the "VHF Communications" publication, Wolfgang Schneider (DJ8ES) described a "Logarithmic Detector amplifier up to 500MHz" utilizing an "AD8307" device. [1] This device is from Analog Devices and is readily available as a traditional in-line package or SMD device. It is an RF detector that will provide a dB linear output. Close examination of the DJ8ES circuit, led me to feel that this device would be ideal to form the basic building block of my "noise meter".

If I tapped off some wideband signal at the 144MHz output from my transverters then I could use this to drive the AD8307 to give me a useable and calibrated detector voltage to drive a meter. Close inspection of the specifications of the AD8307 shows that it's claimed dynamic range of 90dB is useable between -75dBm and +17dBm. [2] As such the RF levels required far exceeded that which one would normally be expecting to encounter in a typical receiver system.

GOING THROUGH THE DESIGN PROCESS:

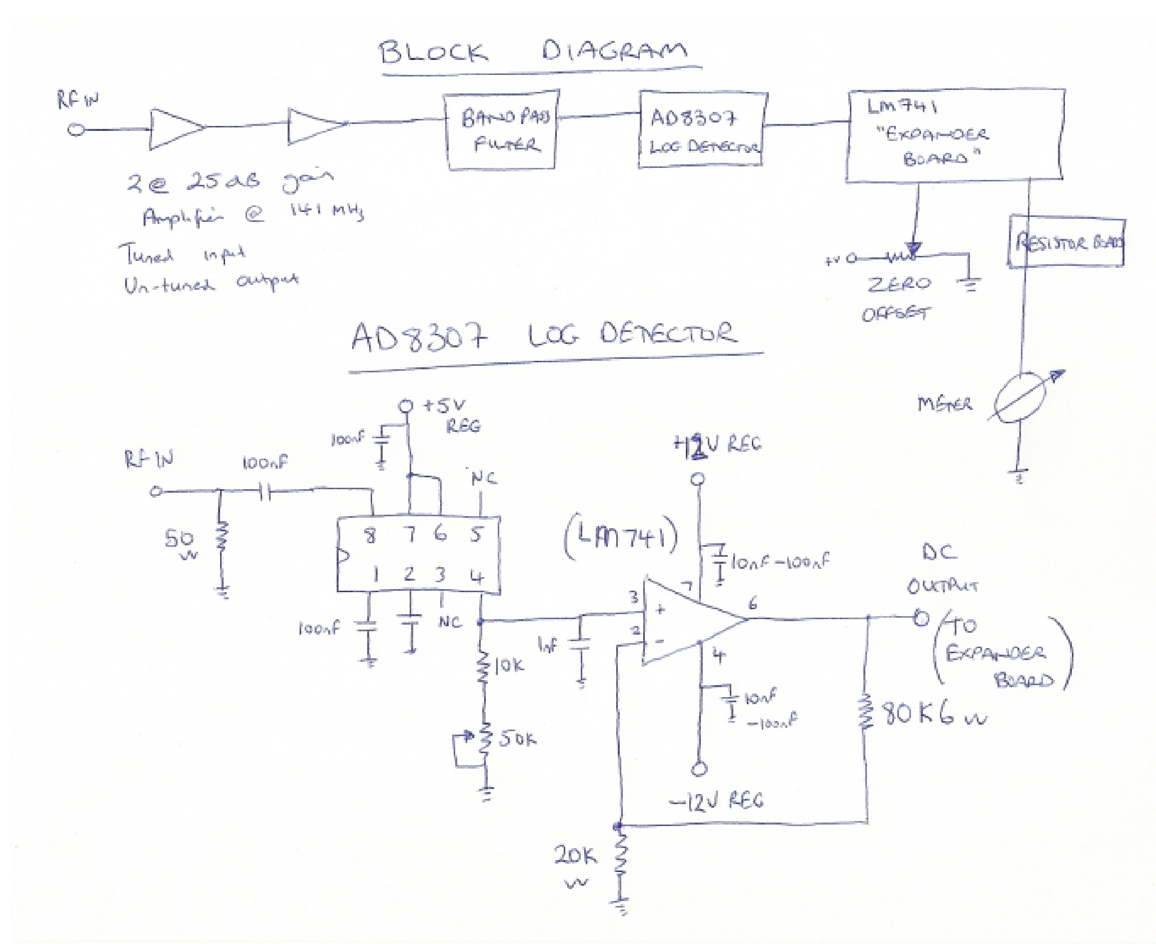
If the received RF signal in the microwave region is around -150dBm as an example, one might expect about 20dB gain in the LNA and another 20dB conversion gain from the transverter. Our signal at the IF frequency is likely to be around -110dBm. This is still well short of the minimum -75dBm required by the AD8307. As such some further amplification is required.
I decided to use approximately 50dB of gain ahead of the AD8307. (In my EME setup at home I use another amplifier ahead of this to put the signal levels around the middle of the range for the AD8307).

By putting some amplification ahead of the AD8307, it also provides the opportunity to place a wideband filter at around 141MHz.

So having decided on this approach the “Noise Meter” circuit was developed.

Please note that whilst the RF part of the system was designed around 144MHz any frequency up to 500MHz could be used.

BLOCK DIAGRAM and AD8307 LOG DETECTOR:



The block diagram described above shows the 2 stages of amplification and a Band pass filter ahead of the detector. These were centered on 141 MHz and the band pass filter exhibits a 4MHz -3dB BW.

All the important electronics comes after the detector.

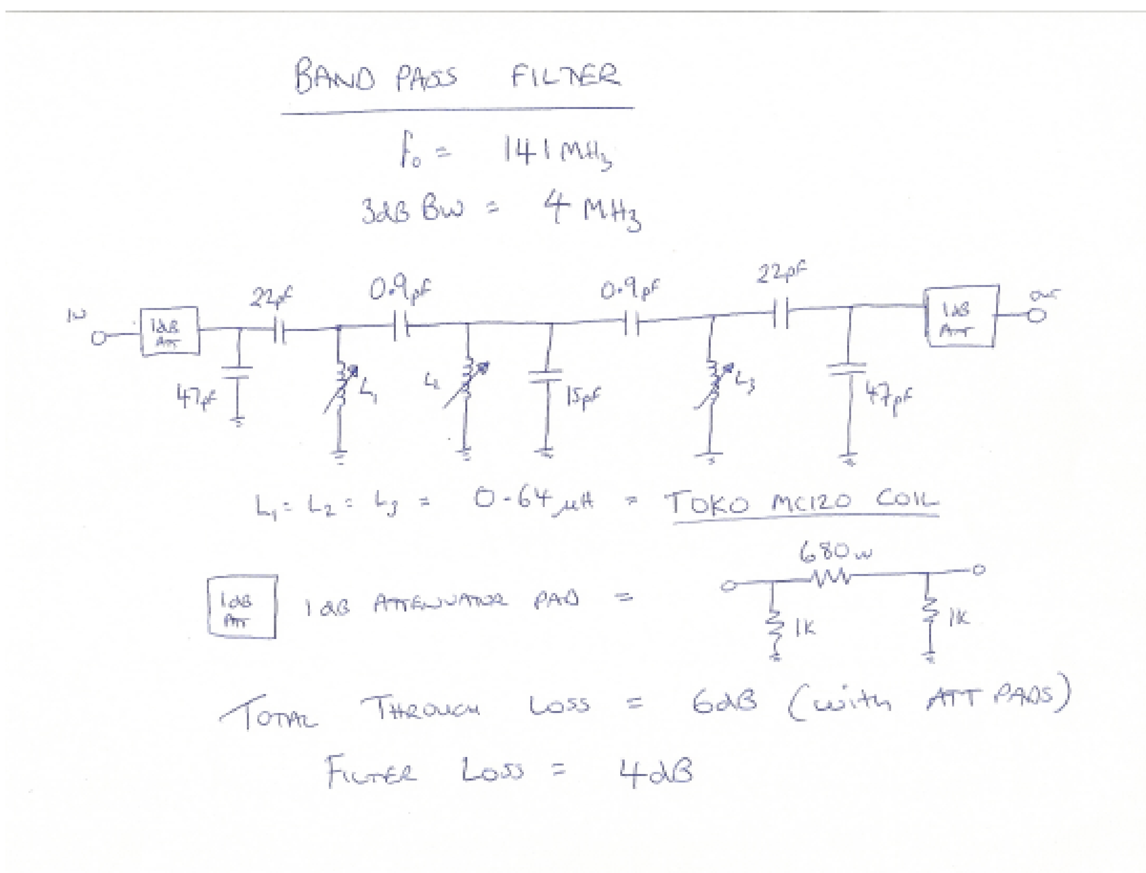
For an Input of +10dBm into the detector board a DC voltage of +10V is available after the LM741. An input of -60dBm produces +3V. There is a little variation from true linearity and the 50k pot helps to balance this out.

The 741 in my detector circuit replaces the original LM358 chip in the DJ8ES circuit but it is still configured as a X5 amplifier. The output is 100mV / dB.

Please refer to the original article by DJ8ES for a thorough description on this board and for ideas on the practical construction and setup.

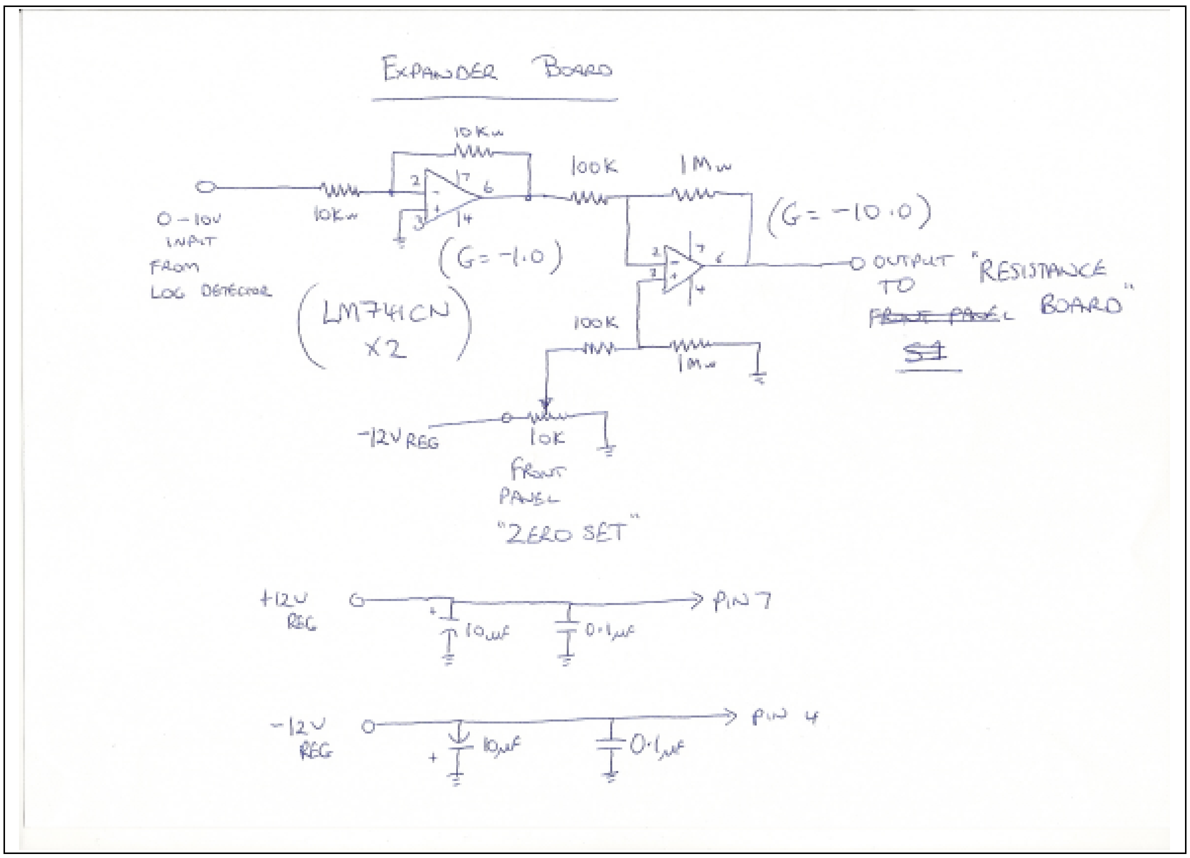
The RF "Preamplifiers" can be of any useful or handy design. A simple amplifier built "ugly" style would be fine using modern MMICS. I built some very simple amplifiers using "TUNED INPUT, UNTUNED OUTPUT" designs around some NE42484A GasFETs.   Any suitable rated amplifier for the chosen frequency can be utilized.

BAND PASS FILTER:



Once again if a different IF is used a suitable filter will be required. One could leave the filter out all together and rely on the output filtering of the transverter but it was reasoned that some additional filtering would be a good idea because of the high level of amplification in the overall system. The filtering would help keep out any spurii. and the whole system is designed in 50 ohms.

EXPANDER BOARD:



A DC voltage of ~0 V - +10 V is available from the output of the log detector board and applied to the input of the expander board in all ranges but the "FULL" range as selected via the front panel switch. In the full range the output of the detector board is fed directly to the "Meter Resistance board".

In the EXPANDER board, the first LM741 is configured as a X1 inverting DC amplifier and the second LM741 is configured as a X 10 inverting "difference" amplifier. The reference DC Offset voltage is supplied via a Front Panel Pot. It would be best to use a Multi-turn pot for this application as it makes "zero adjustment" easier.

Examining the function of the Expander Board :

EXAMPLE 1:

Let's assume a signal of -20dBm produced +7V out of the detector board. When this is applied to the 1st LM741 a DC voltage of -7V is produced at pin 6. This is then applied to the 2nd LM741 via the 100k resistor to pin 2. At the same time a –ve voltage is applied via the 100k resistor to pin 3. This –ve voltage is determined by the "Zero Adjust" front panel pot. If the signals applied to Pins 2 & 3 are the same the difference is 0 and there will be 0V at pin 6.

Let's assume now that we have set the front panel pot to produce 0V out of the expander board, and now the signal level at the 50 ohm input of the log detector goes from -20dBm to -10dBm (10dB increase - for example Sun Noise) then the output of the detector board goes from +7V to +8V. The output of the expander board will now go to +10V ($V_{difference}$ X10).

This voltage can now be fed to the resistance board to drive the meter as an indication of 10dB. If the appropriate resistance and meter combination is used this might be setup to represent Full Scale Deflection of the front panel meter.

EXAMPLE 2:

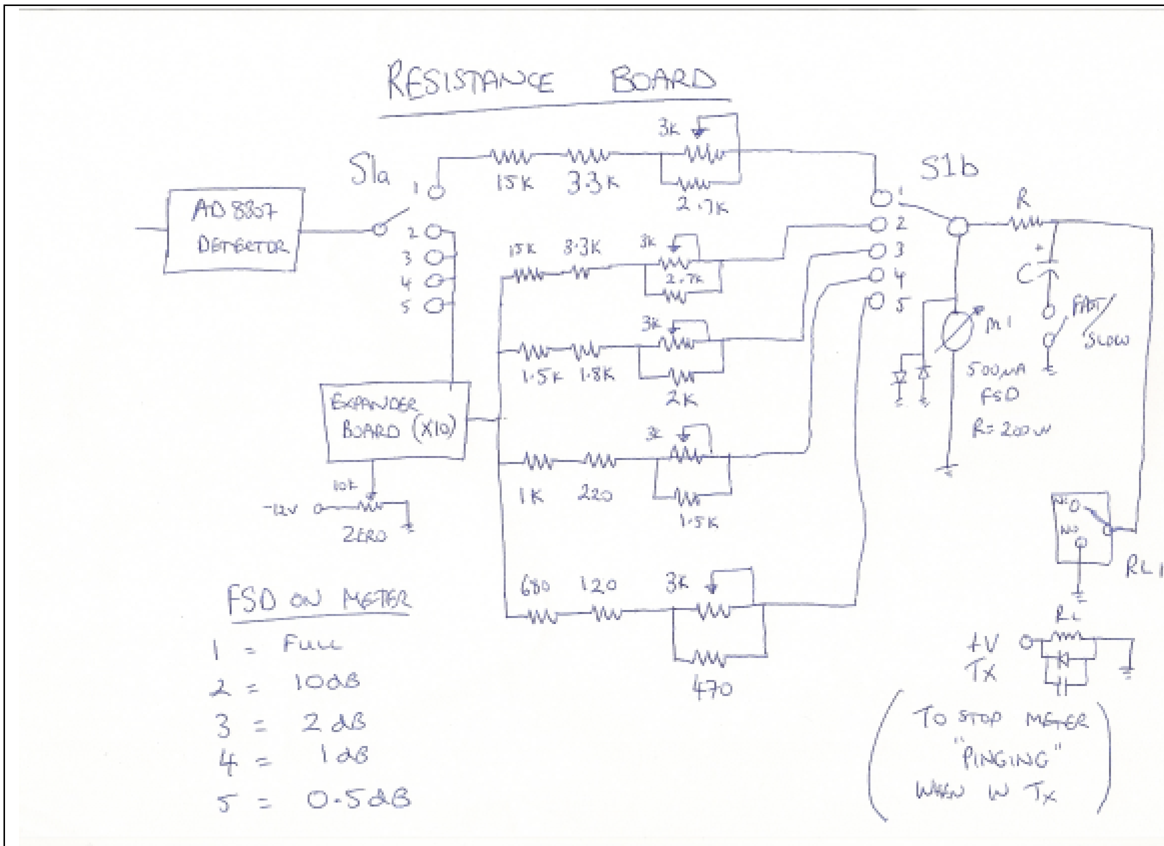
-20dBm input to detector (ie. pointing at cold sky) results in +7V at the input to expander board. The Zero Offset pot is set so there is no voltage on the output of the Expander board (ie. -7V at pin 3 of the 2nd LM741)
Now a signal of -19dBm input at the detector appears (ie. 1dB moon noise as the dish is pointed at the moon). A DC voltage of +7.1V appears at the input of the expander board, so a DC voltage of 1V appears at the output.

This Voltage can now be fed to the resistance / meter combination in such a way that 1V causes a Full Scale Deflection. That is FSD = 1dB.

In practical application I found that the meter can have a FSD representing as little as 0.5dB increase in input level and still have excellent stability and accuracy as verified with a HP Signal generator as the calibrating source.

The Absolute input levels are not critical (provided they are within the useable range of the AD8307). The RELATIVE MEASUREMENTS ARE VERY ACCURATE provided care is taken in setting up the response of the AD8307 and calibrating the resistance multipliers correctly.

RESISTANCE BOARD:



The schematic of the resistance board helps show how the various “blocks” come together.

The actual values will depend on the required FSD RANGE and the meter characteristics / specifications.

I used a 2 pole 5 position front panel switch to select between:

- Full
- 10dB
- 2dB
- 1dB
- 0.5dB   FSD ranges.

In the FULL range the "Absolute" front panel meter calibration is dependant on the gain ahead of the Log Detector board. It should be calibrated against a very accurate signal generator.

The calibration of the meter with the various range selection is linear in fashion. There is a slight variation between devices and in experimenting it was found a lot depends on the absolute input level and frequency and the setup of the detector board to start with.

In my unit I found a Maximum error of 5%.

SUMMARY OF METER RESISTANCE BOARD:

For FULL Range:
Select meter / resistors so 0-10 V gives FSD

For 10dB Range:
Select meter / resistors so 0-10 V from Expander board output gives FSD

For 2dB Range:
Select meter / resistors so 0-2 V from Expander board output gives FSD

For 1dB range:
Select meter / resistors so 0-1 V from Expander board output gives FSD

For 0.5dB range:
Select meter / resistors so 0-0.5 V from Expander board output gives FSD

MISCELLANEOUS:

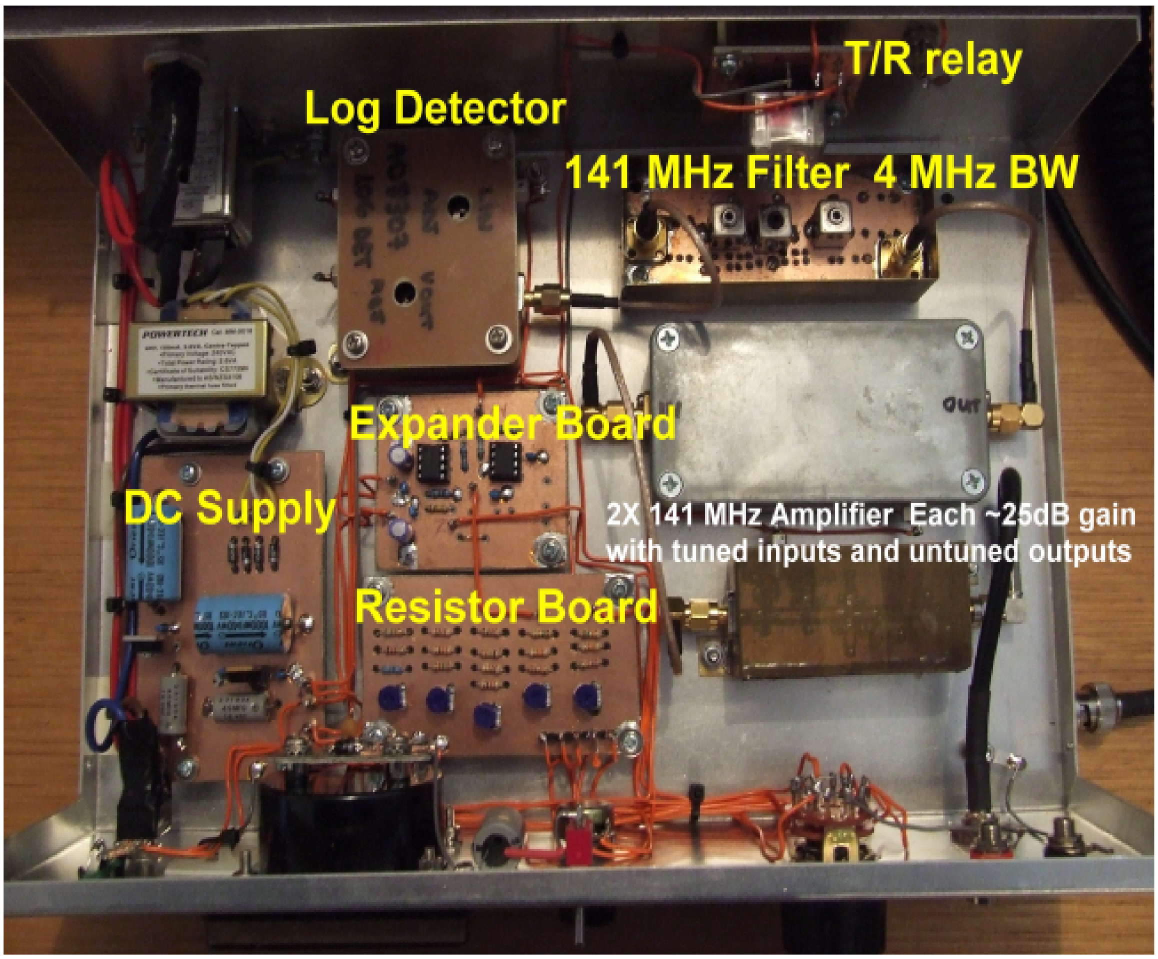
- Regulated + 12V and -12 V supplies are required for the various boards as indicated.
- The FAST/SLOW switch is self explanatory and adds a capacitor / resistor time constant for the meter to smooth out movement IF required.
- The "Anti Pinging" relay is a must for T / R changeovers.
- The back to back diodes across the meter will help limit voltage across the meter to prevent damage.
- For accuracy and ease of use the biggest faced panel meter possible should be used.
- Proper decoupling of RF on all DC lines is required.

PICTURES:

The absolute calibration is on the bottom of the meter scale. My unit has amplification such that FSD in the full range is -20dBm at the front panel RF IN connector.

In my EME system, the usual RF input to the front panel BNC is between -60dBm and -75dBm depending on the transverter. With 50dB of gain before the LOG detector this means the AD8307 is operating around -10dBm to -25dBm. Well within specification.

A direct DC output at 100mV / dB (from the detector board) is available at the banana style connectors for use with an external "recorder" type device.



Practical Implementation:

In my EME system I use a Receive splitter on the output of my 144 MHz IF of my Transverters.
This unit has a T/R relay and when in receive mode, it splits the Rx signal into 2 paths:

- 1 signal path goes to my 144MHz IF radio
- The other Rx signal path is further amplified with a MMIC by about 20dB and filtered with a simple series tuned filter tuned to a centre frequency of 141 MHz.

This amplified Rx signal is then applied to the "Noise Meter" input front panel BNC.

During operation the "coldest part of the sky" is found with the dish and the meter Zero Adjust is used to set the reference level in one of the smaller ranges. The dish is then pointed at the moon and it is very obvious in the 0.5, 1 and 2dB ranges when I have the dish pointed accurately. During EME operation, I "re-peak" for moon noise during Receive sequences.

Calibration of the dish Azimuth and Elevation indication system can then be easily checked and adjusted, or if the calibration is close than manually peaking the dish on moon noise gives absolute confidence that the dish is pointed accurately.

With my "actuator" based system of dish control the noise meter has become a valuable and irreplaceable instrument to carry out EME activity on the higher microwave bands (9cm and up).

REFERENCES:

(1) Logarithmic Amplifier Up to 500 MHz with AD8307. Wolfgang Schneider, DJ8ES. VHF COMMUNICATIONS Vol. 32 Summer 2000 – Q2

(2) Data Sheet AD8307. Analog Devices, Inc. 1997

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