SOAREX GROUP

My Approach to an S-Meter

Dave VE3OOI

July 2023

Danger Will Robinson…

Quote Charlie Morris, ZL2CTM:

This NOT a tutorial.

It's a log of my journey. Right or wrong.

AGENDA

1. Fundamentals: What is an S-Meter?
2. Some approaches to S-Meters
3. Peak Detector
4. Logarithmic Amplifier

FUNDEMANTALS

From Wikipedia, the free encyclopedia

Not to be confused with Field strength meter.

An **S meter** (signal strength meter) is an indicator often provided on communications receivers, such as amateur radio or shortwave broadcast receivers. The scale markings are derived from a system of reporting signal strength from S1 to S9 as part of the R-S-T system. The term **S unit** refers to the amount of signal strength required to move an S meter indication from one marking to the next.

Signal strength	Relative intensity	Received voltage		Received power ($Z_c = 50\ \Omega$)	
S1	−48 dB	0.20 μV	−14 dBμV	790 aW	−121 dBm
S2	−42 dB	0.40 μV	−8 dBμV	3.2 fW	−115 dBm
S3	−36 dB	0.79 μV	−2 dBμV	13 fW	−109 dBm
S4	−30 dB	1.6 μV	4 dBμV	50 fW	−103 dBm
S5	−24 dB	3.2 μV	10 dBμV	200 fW	−97 dBm
S6	−18 dB	6.3 μV	16 dBμV	790 fW	−91 dBm
S7	−12 dB	13 μV	22 dBμV	3.2 pW	−85 dBm
S8	−6 dB	25 μV	28 dBμV	13 pW	−79 dBm
S9	0 dB	**50 μV**	34 dBμV	50 pW	−73 dBm
S9+10	10 dB	160 μV	44 dBμV	500 pW	−63 dBm
S9+20	20 dB	500 μV	54 dBμV	5.0 nW	−53 dBm
S9+30	30 dB	1.6 mV	64 dBμV	50 nW	−43 dBm
S9+40	40 dB	5.0 mV	74 dBμV	500 nW	−33 dBm
S9+50	50 dB	16 mV	84 dBμV	5.0 μW	−23 dBm
S9+60	60 dB	50 mV	94 dBμV	50 μW	−13 dBm

2mV to 200nV
(10K order of magnitude to measure!!)

FUNDEMANTALS

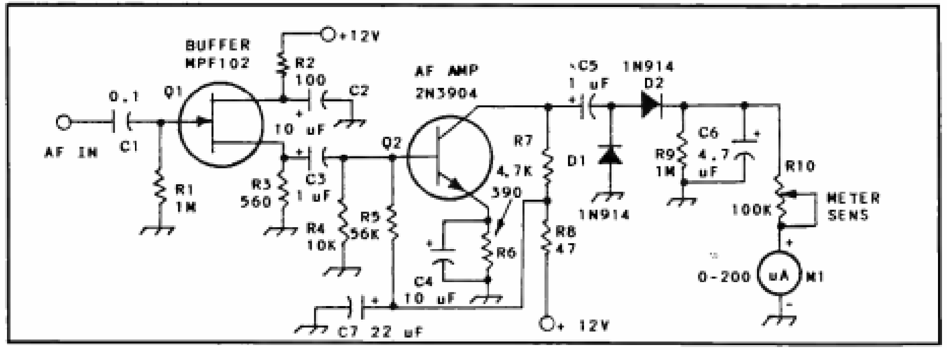
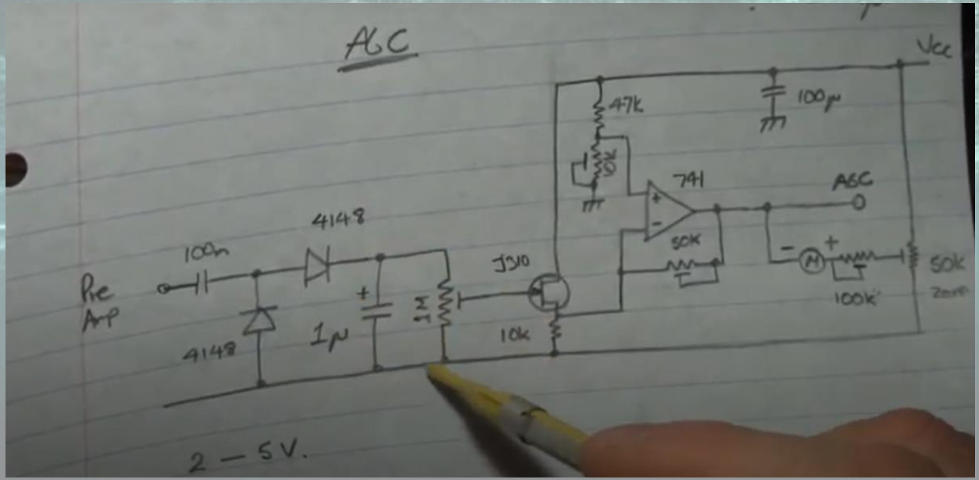


Figure 1: Schematic diagram of the audio-derived S meter. Capacitors are in uF. Polarized capacitors are electrolytic or tantalum. Fixed-value resistors are 1/4 watt. R10 is a PC mount carbon composition trimmer control. Q1 can also be a 2N4416 or other N-channel JFET. Q2 can be a 2N2222, 2N4400 or similar device.

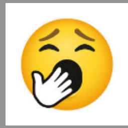
https://worldradiohistory.com/hd2/IDX-Short-Wave/Monitoring-Times-IDX/90s/Monitoring-Times-1992-02-OCR-Page-0100.pdf



(Charlie Moris) https://youtu.be/sDvVYFXFpMA

1. **There are MANY analog S-meter circuits created by people much smarter than me**
2. **Majority take signal from audio output before AF amp.**
3. **Many times, the circuit is used for AGC. Signal is from the IF stage and not the audio stage.**
4. **The challenge is properly detecting and displaying signals that vary by 10,000**

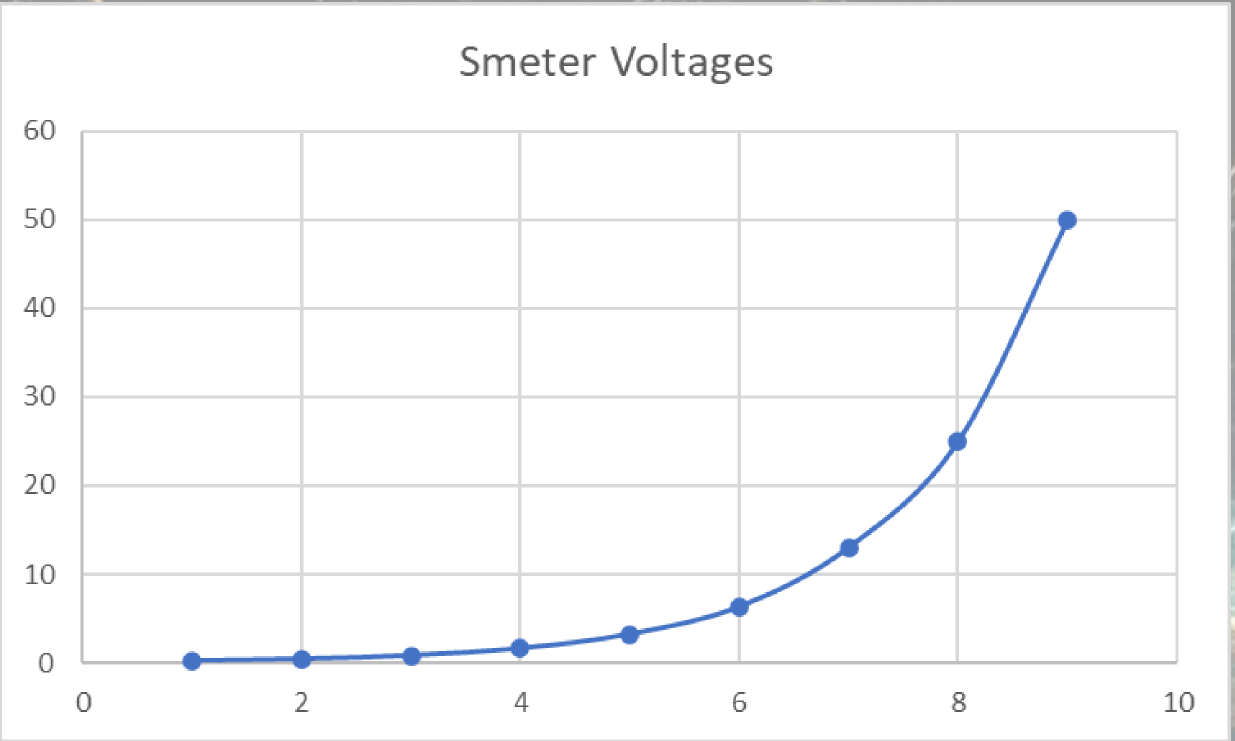
FUNDEMANTALS



S	uV
1	0.2
2	0.4
3	0.79
4	1.6
5	3.2
6	6.3
7	13
8	25
9	50
S9+10	160
S9+20	500

Range of small to large number

2,500 x increase



Logarithms rescue us from having to process both large numbers as well as extremely small numbers.

FUNDEMANTALS

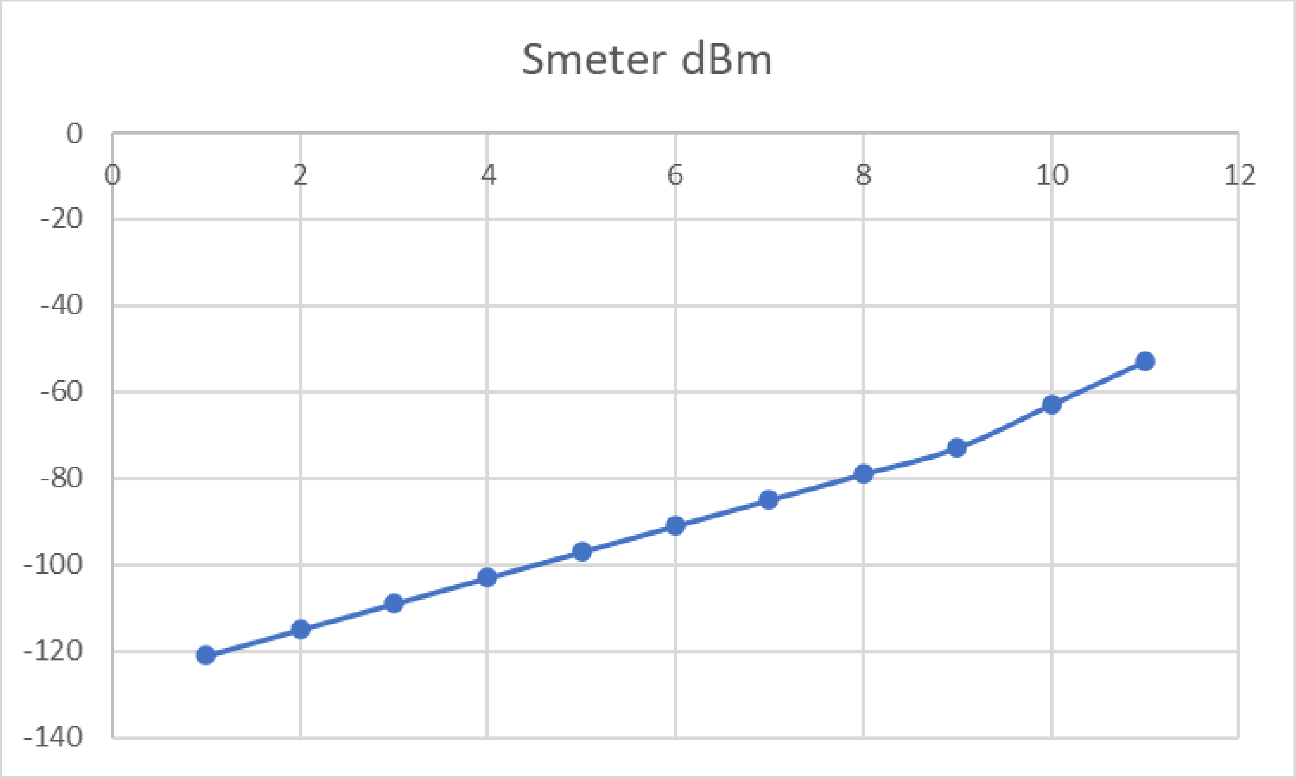
Logarithms rescue us from having to process both large numbers as well as extremely small numbers.

S	dBm
1	-121
2	-115
3	-109
4	-103
5	-97
6	-91
7	-85
8	-79
9	-73
S9+10	-63
S9+20	-53

Smaller Range

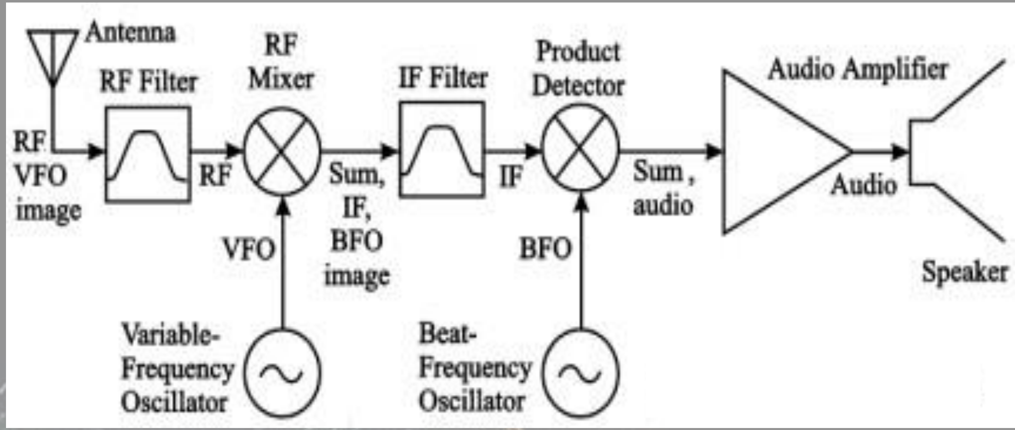
Less than 3x increase

Notice values differ by 6dB!



Using Logarithm of the numbers, we can more easily VISUALIZE and PROCESS them.

APPROACHES



1. **Measure signal at source input**
   - **Will need to measure RF signal**
   - **Will be difficult to isolate signal of interest from the “band”**
   - **Will be dependent on RF gain**

2. **Measure signal after IF amplifier**
   - **Will need to measure RF signal**
   - **Will be dependent on RF gain**

3. **Measure Audio signal**
   - **Will be dependent on RF gain**
   - **Will be dependent on AF gain (maybe)**

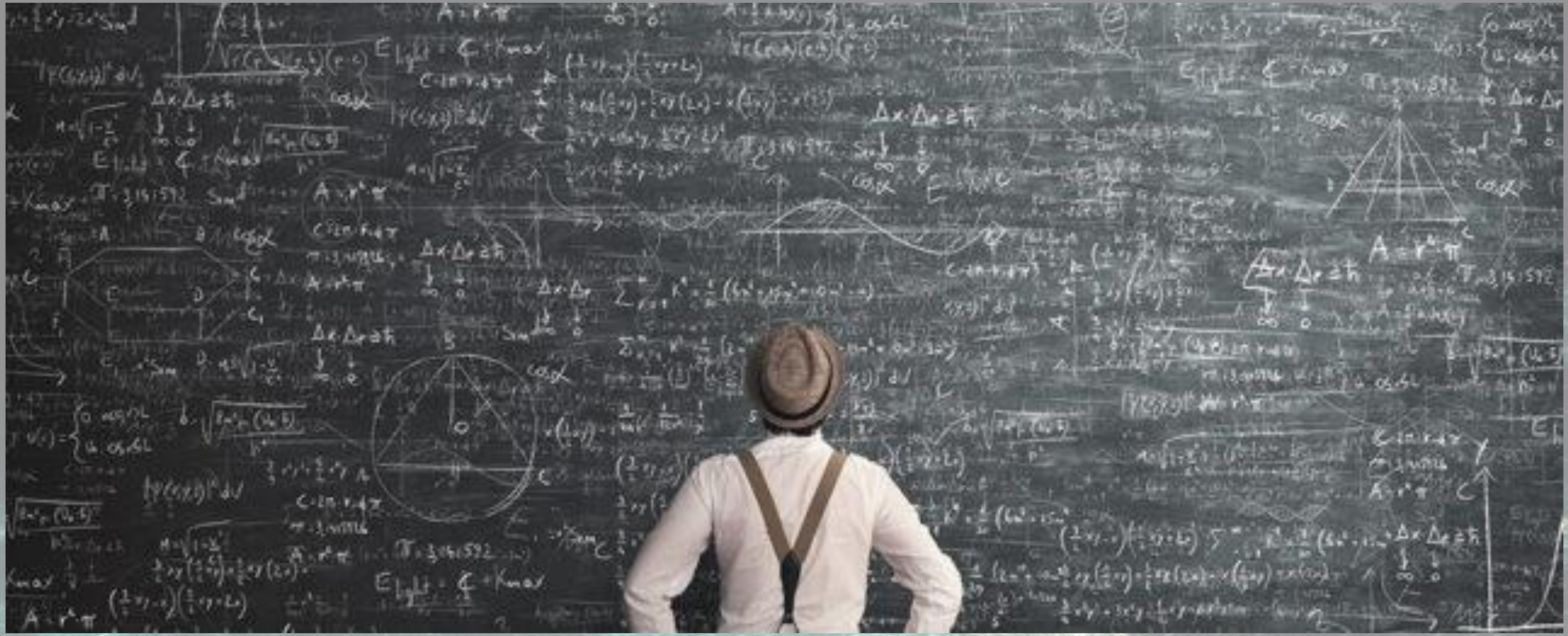
APPROACHES: ANALYSIS

1. **Measure RF Signals**
   - ➢ Use Diode Detector
     - ❖ Weak signals will need amplifier
     - ❖ Use a uA meter (lots of samples)
   - ➢ Use AD8307 Log Amp
   - ➢ Higher complexity but more accurate

2. **Measure Audio signal**
   - ➢ Simpler to measure* and filter
   - ➢ More noise (e.g., induced noise, due to other unwanted byproducts)
   - ➢ Lower complexity* but less accurate, less sensitive?

*Yea Right!!

FOREST FROM THE TREES



1. **What's the goal here?**
2. **How accurate does this need to be?**
3. **Is an S-Meter a precise instrument?**

KISS

FINAL APPROACH

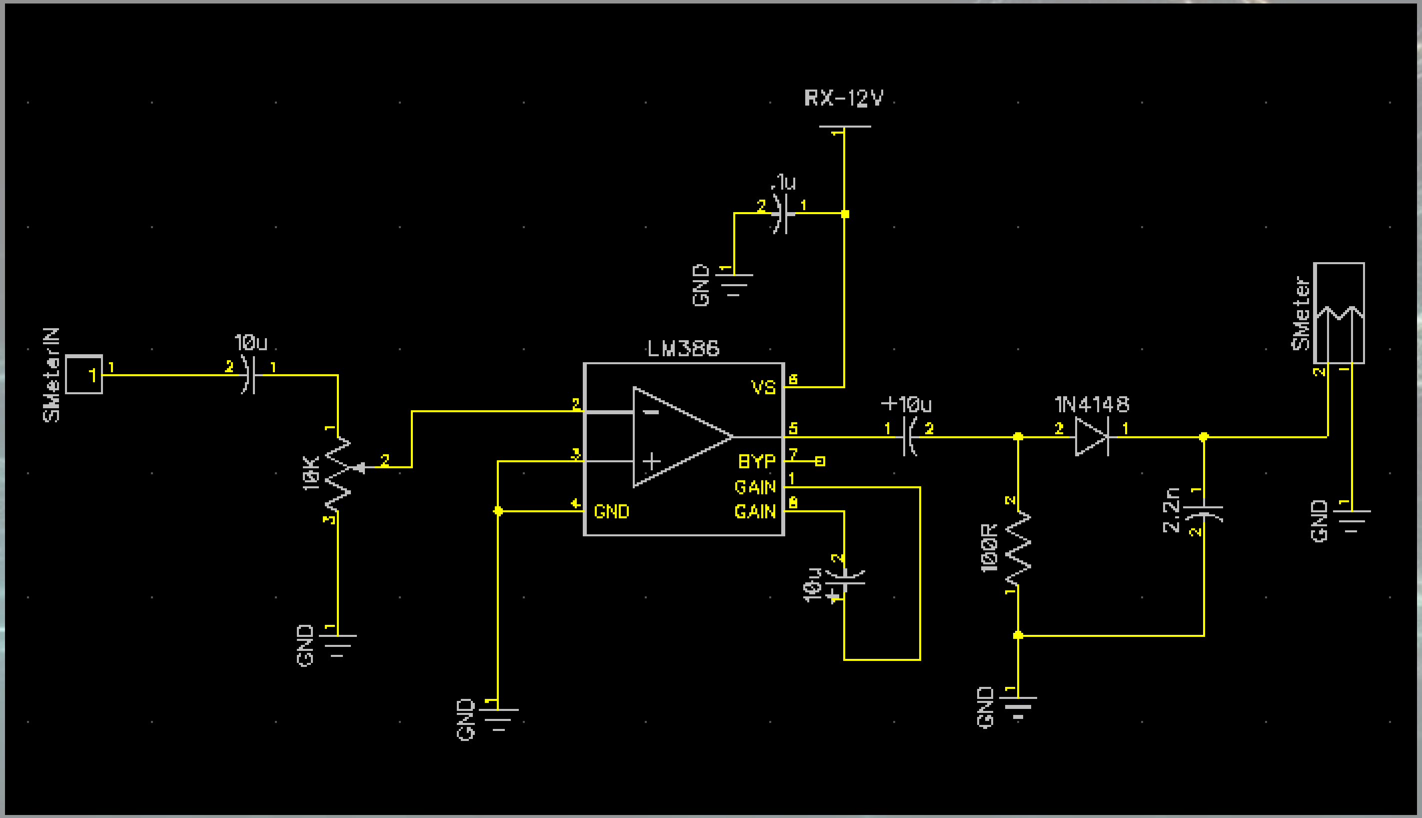
1. Measure audio before final AF Amp

2. Apply filtering to clean up noise

3. Use digital measurement (i.e., uC ADC)
   - ✓Use uC software
   - ✓Reduce hardware for smallest footprint

4. Use Opamps. KISS

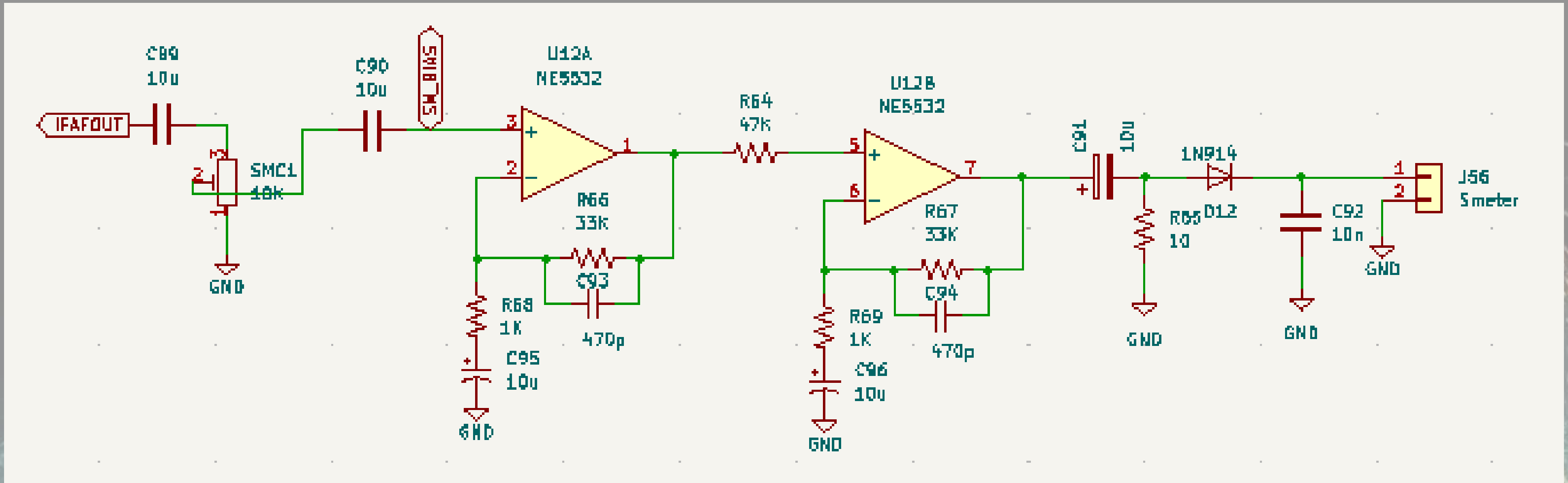
PREVIOUS APPROACH: D612



1. This worked “relatively” well.
2. PIA to calibrate and implement in software

Innovate!

APPROACH #1: Wing it



Not properly tested

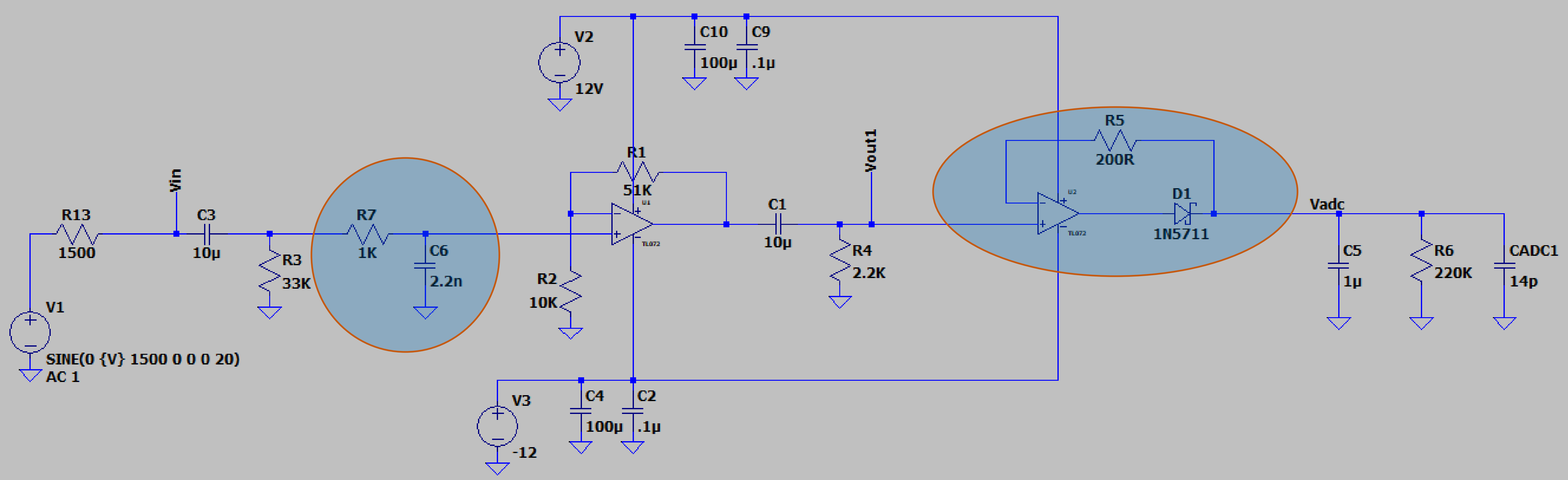
- ✓ I simulated and built PoC for almost all Phoenix components, ***except this***

Issues:

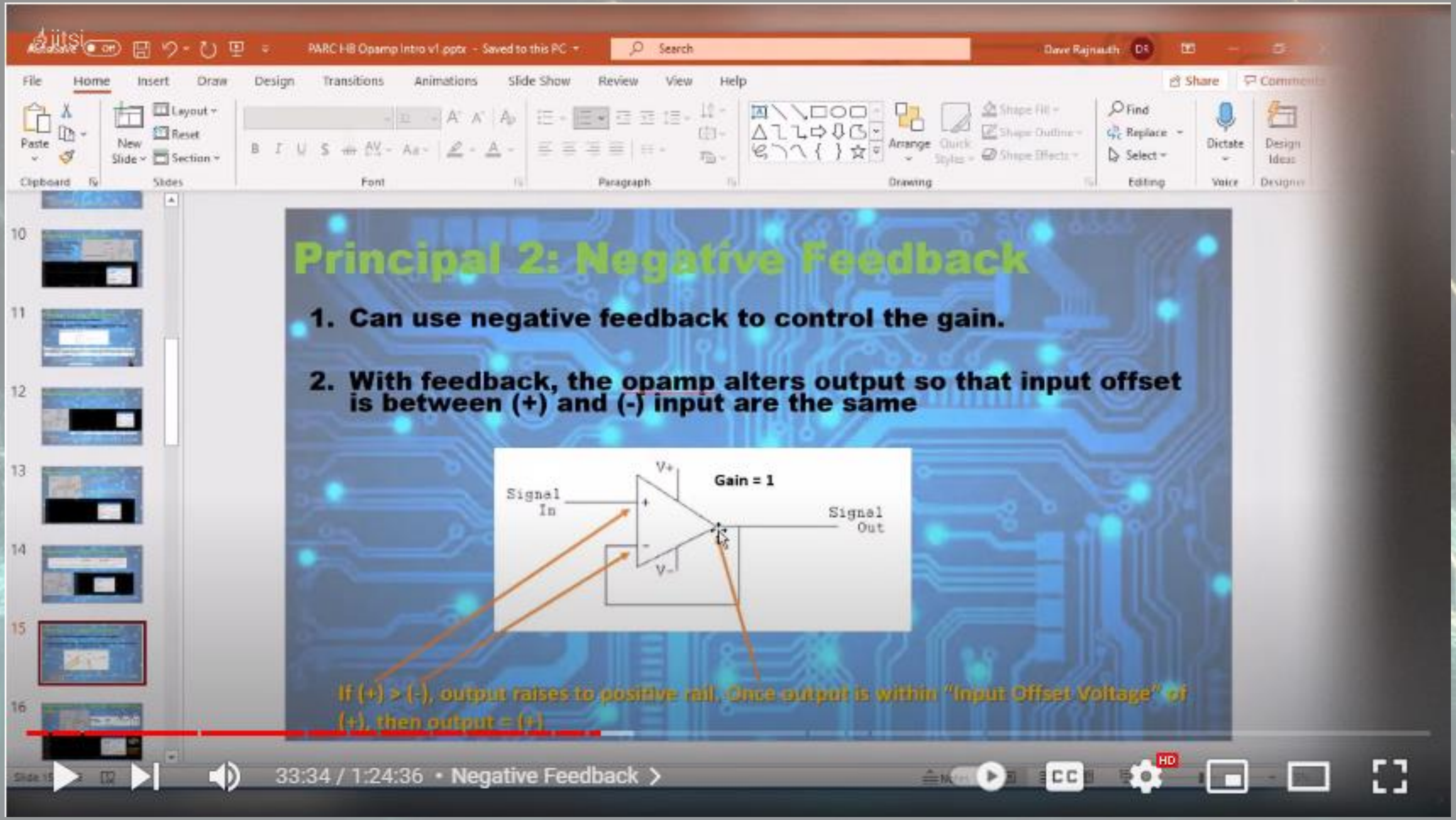
1. **Too wide dynamic range**
2. **Opamps single supply and clipped**
3. **Voltages too high for ADC.**

Innovate!

APPROACH #2: Peak Detector

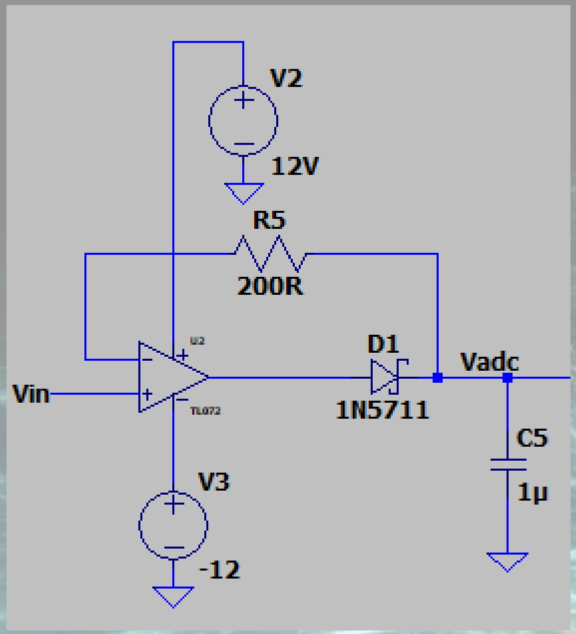


Watch my OPAMP presentation to understand how OPAMPs work



https://youtu.be/rTIbfG0pels

Peak Detector: How it Works



1. **Both +Input must be equal to –Input**

2. **If +Input is larger than –Input, Opamp increases output until inputs are equal. Max is +Rail Voltage (+12V)**

3. **If +Input is smaller than –Input, decreases outputs until inputs are equal. Min is -Rail Voltage (-12V)**

4. ***Diode blocks output until output is 0.7V. Anything below zero results in diode negative bias and voltage is not passed through***

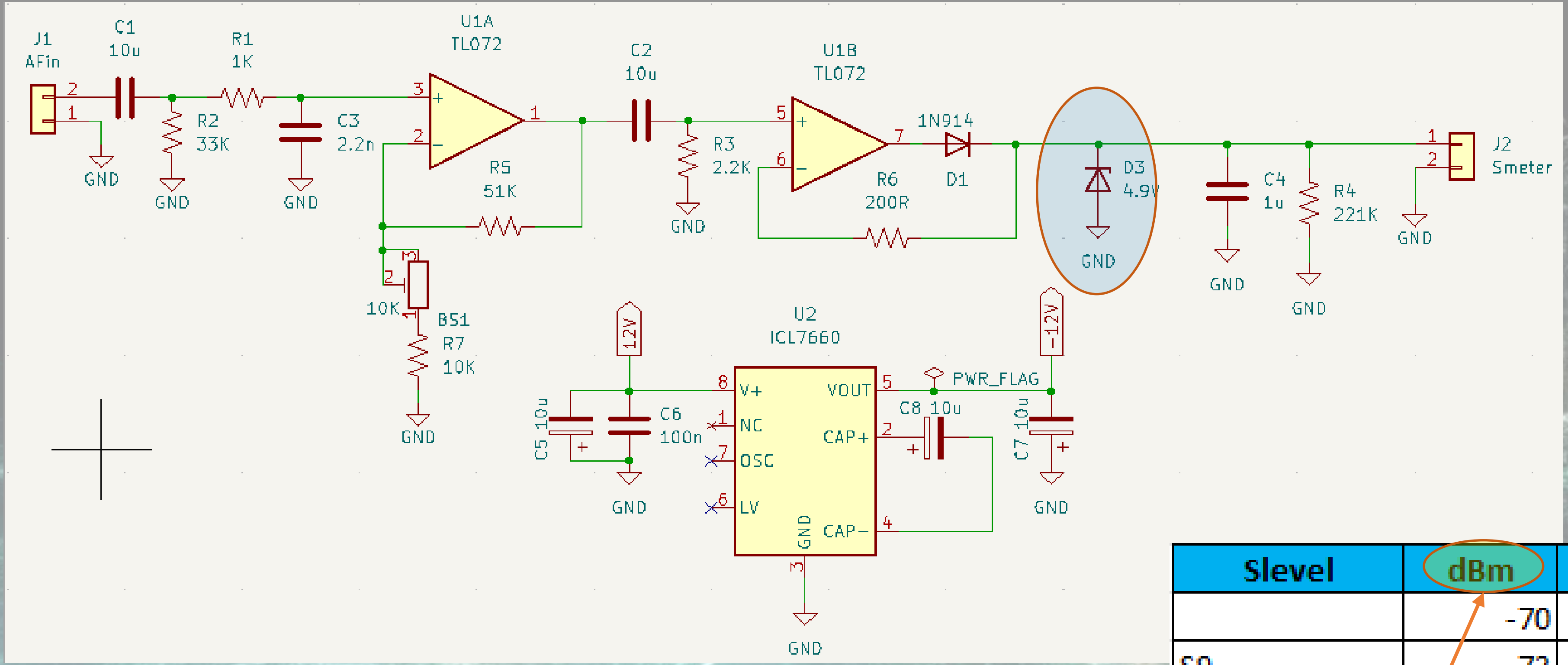
   Note: A small positive voltage at V+ causes Vout to rapidly increase to +Rail

5. **Only positive "humps" are fed through the opamp.**

6. **Capacitor smooths humps to a DC level (with some ripple)**

7. **Since opamp input is a very high resistance, output is not impacted (i.e., capacitor will not discharge)**

APPROACH #2: Peak Detector



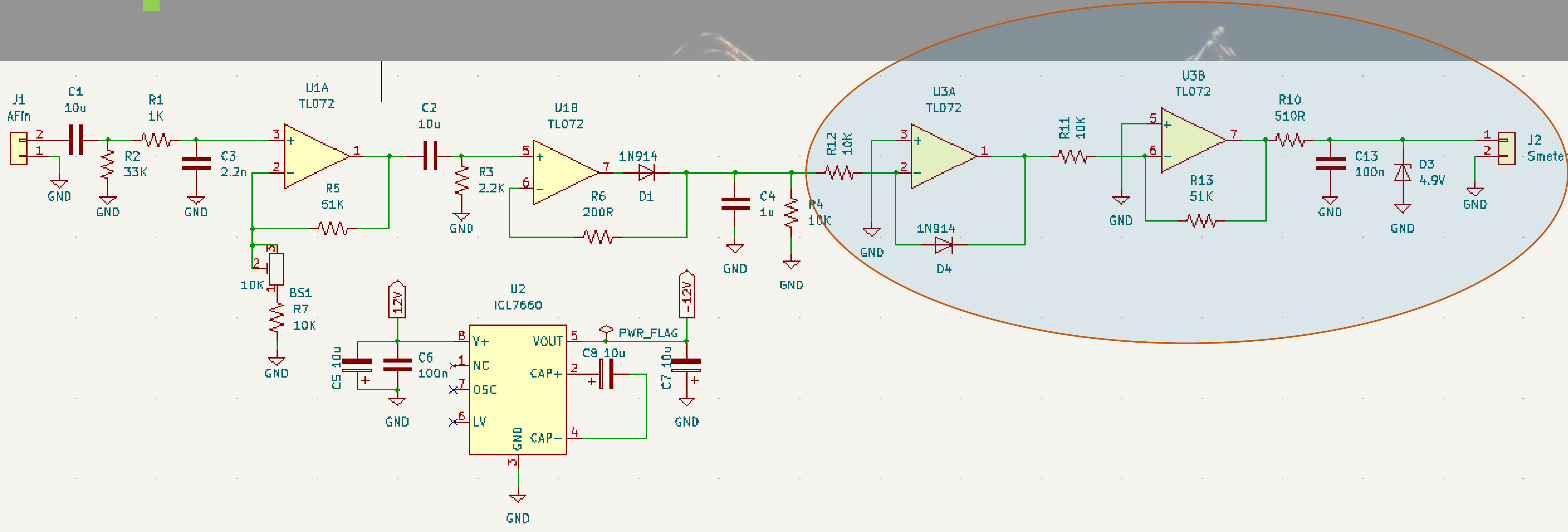
1. Needed negative charge pump
2. Too large dynamic range
3. Exceeded max ADC voltage

Slevel	dBm	Vpp	Vp	Actual db
	-70	10.6	4.7	
S9	-73	7.6	3.8	1.85
S8	-79	3.9	1.9	6.02
S7	-85	1.9	0.951	6.01
S6	-91	1.01	0.498	5.62
S5	-97	0.472	0.248	6.06
	-100	0.348	0.182	2.69

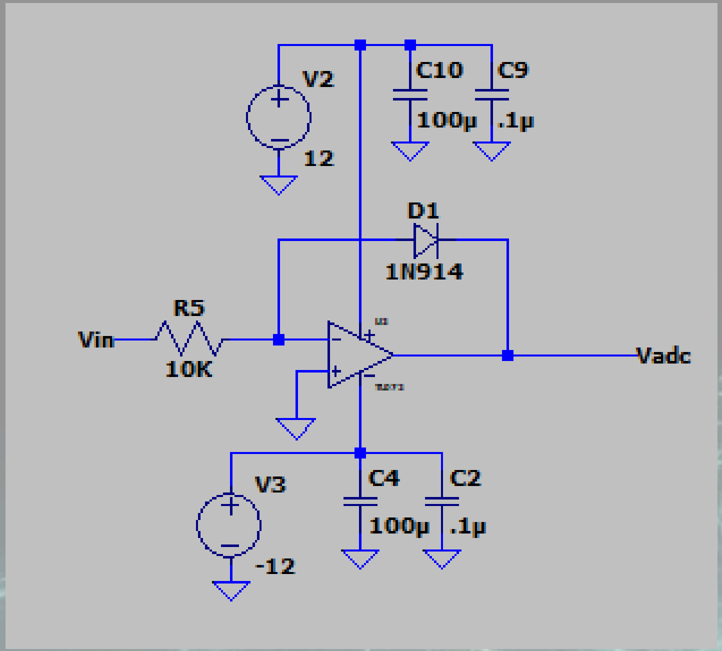
Power Fed Into Phoenix

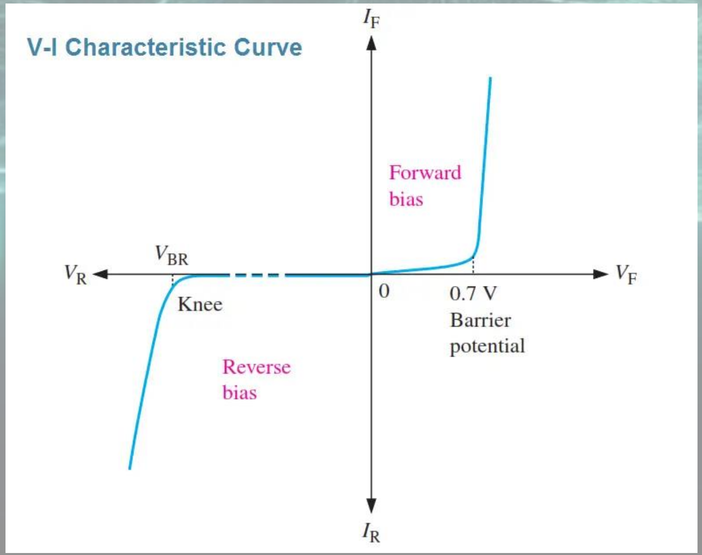
ADC Max & Min

APPROACH #3: Peak Detector + Log Amp



Log Amp: How it Works





1. **When the –Input terminal is greater than +Input terminal, the output must swing to –Rail and diode conducts. A current flow through the diode.**

2. **Since no current flows into opamp (infinite input impedance), All current from Vin must flow through Diode**

$$I_D = I_0 \left(e^{\frac{V_f}{\eta V_T}} - 1\right)$$

I_0 is Saturation Current (constant), nV_T is a constant

3. **With clever math, the output voltage is dependent on the log of the input voltage (also resistor and current)**

$$Vo = -\eta V_T \log \frac{V_{in}}{I_0 R}$$

4. **The output voltage is proportional to the log of the input voltage**

APPROACH #3: Peak Detector + Log Amp

S	dBm	Vpeak (mV)	Vlog (V)	Difference
S1	-120	19.8	1.44	
S2	-115	26	1.56	0.12
S3	-109	43.6	1.69	0.13
S4	-103	63.4	1.85	0.16
S5	-97	181	2.01	0.16
S6	-91	349	2.18	0.17
S7	-85	651	2.36	0.18
S8	-79	1036	2.51	0.15
S9	-73	2710	2.66	0.15
S9+10	-63	7800	2.89	0.23
S9+13	-60	8050	2.91	0.02
	-57	8260	2.91	
	-55	7890	2.91	

Peak Detector Clipping (aka Distortion)

Need higher voltage supply to Opamp or Rail-to-Rail Opamps

Algorithms: Calibration Woes

1. **For calibration to be simple, need simple algorithm and Smeter accuracy suffers**

2. **When calibration is complex, need “beefer” algorithm and Smeter is accurate**

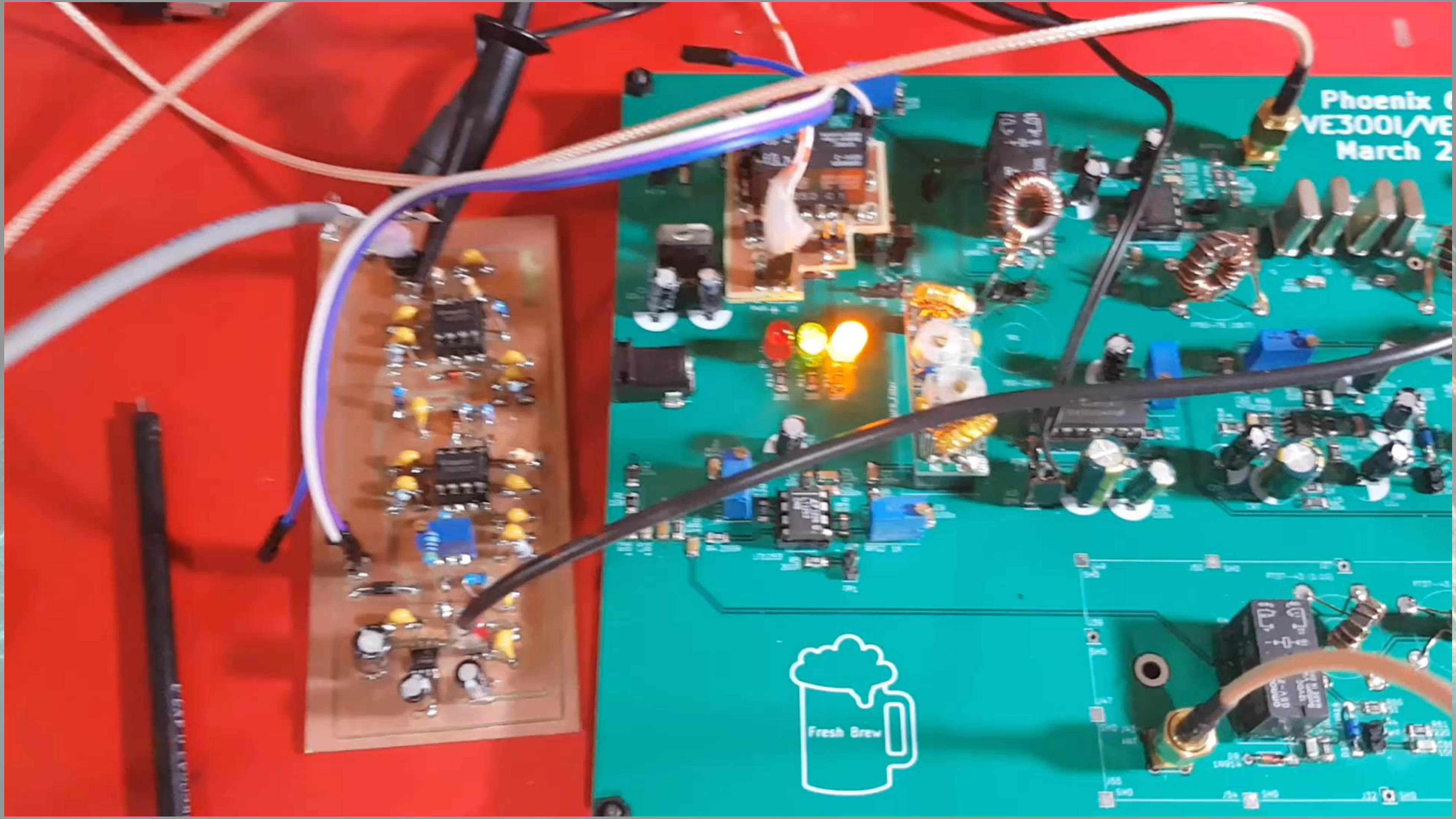
```
sMeter = getSmeterValue(SMETER_SAMPLES);
if (sMeter < 539) bars = 1;
else if (sMeter < 627) bars = 2;
else if (sMeter < 700-16) bars = 3;
else if (sMeter < 772-16) bars = 4;
else if (sMeter < 823-16) bars = 5;
else if (sMeter < 889-16) bars = 6;
else if (sMeter < 940-16) bars = 7;
else if (sMeter < 973-16) bars = 8;
else if (sMeter < 999-16) bars = 9;
else if (sMeter < 1016) bars = 10;
else if (sMeter >= 1016) bars = 11;

if (bars >= MAX_SMETER_BLOCKS) bars = MAX_SMETER_BLOCKS - 1;
if (bars <= 0) bars = 1;

LCDDisplaySmeter((unsigned char)bars);
LCDDisplaySValue((unsigned char)bars);
```

Complex Calibration

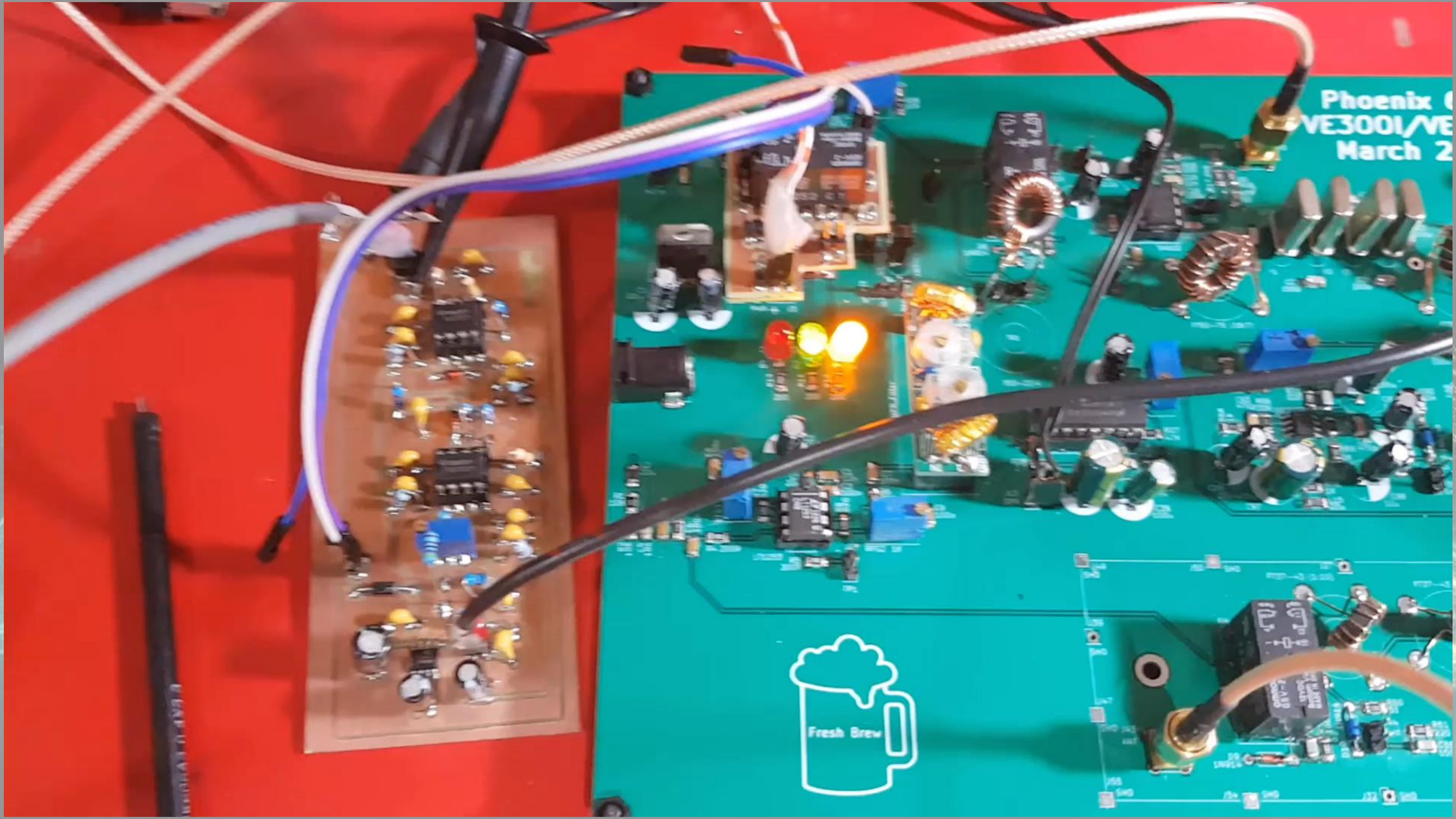
```
sMeter  = getSmeterValue(SMETER_SAMPLES);
if (sMeter > (mem.SmeterBaseline - 10 * mem.SmeterDelta)) {
  bars = sMeter - (mem.SmeterBaseline - 10 * mem.SmeterDelta);

  if (bars >= mem.SmeterDelta) {
    bars /= (float)mem.SmeterDelta;
    if (bars < 2)
      bars = 2;
    else if (bars > 10.6)
      bars = 11;
    bars = int(bars);
  } else {
    bars = 2;
  }

} else {
  bars = 1;
}

if (bars >= MAX_SMETER_BLOCKS) bars = MAX_SMETER_BLOCKS - 1;
if (bars <= 0) bars = 1;

LCDDisplaySmeter((unsigned char)bars);
LCDDisplaySValue((unsigned char)bars);
```

Simple Calibration

SIMPLE SOFTWARE/CALIBRATION



COMPLEX SOFTWARE/CALIBRATION



CONCLUSIONS

Forest from the Trees

- ✓Use Peak Detector with Log Amp.
- ✓Limit use between say S4 to S9+20.
  - ➢Will we REALLY hear a signal below S5 with current noise floor
- ✓Use less or no gain at the front end to allow higher outputs
- ✓MAYBE - Use better Opamps – rail-to-rail Opamps

FIN