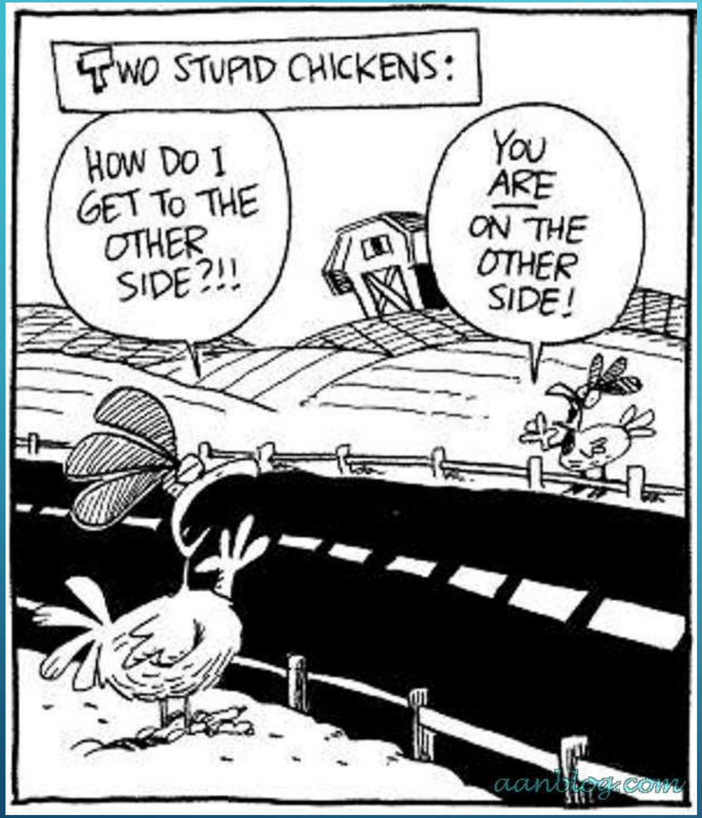
SCALAR NETWORK ANALYZER

HOW IT WORKS

DAVE VE3OOI

DANGER WILL ROBINSON…



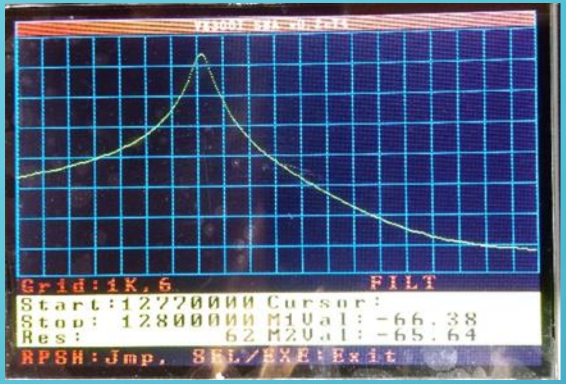
WHAT THIS IS.

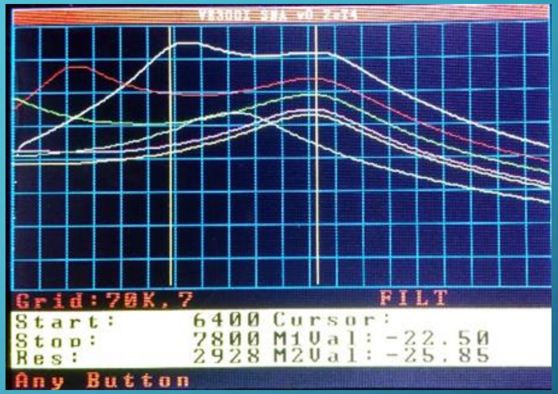
A Basic Introduction

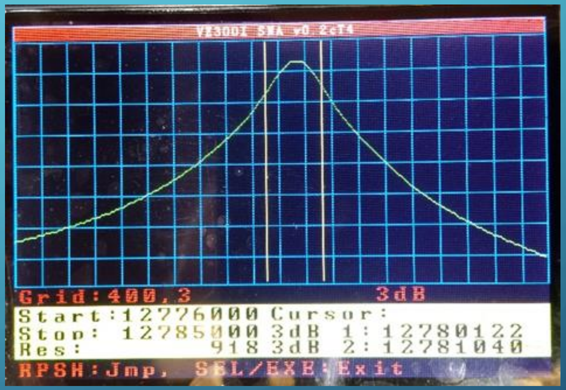
HOW

DOES IT

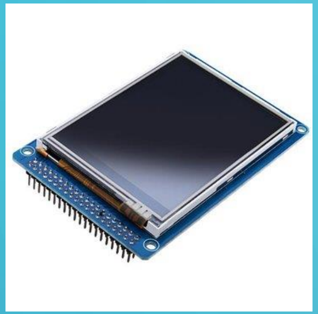
DO THIS?

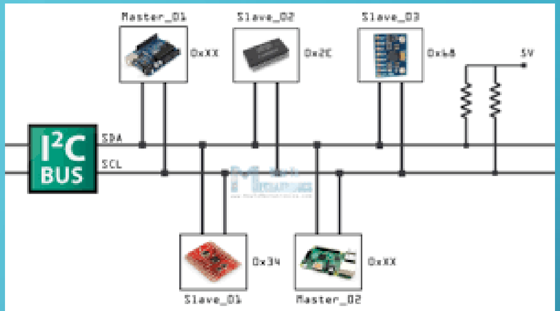


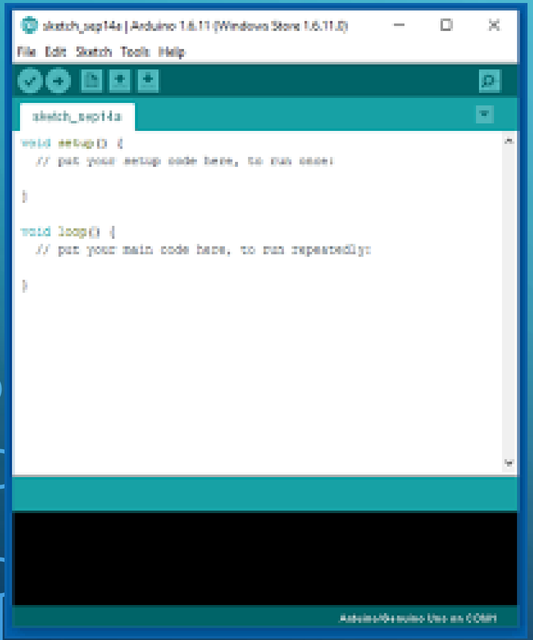


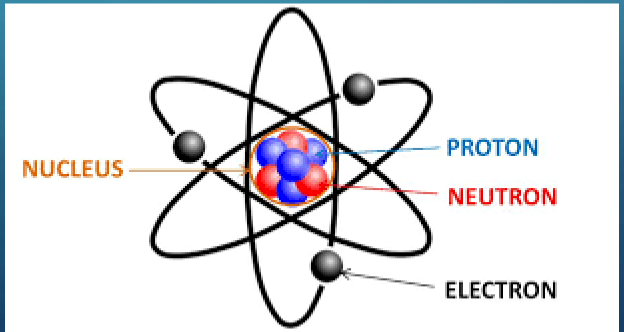


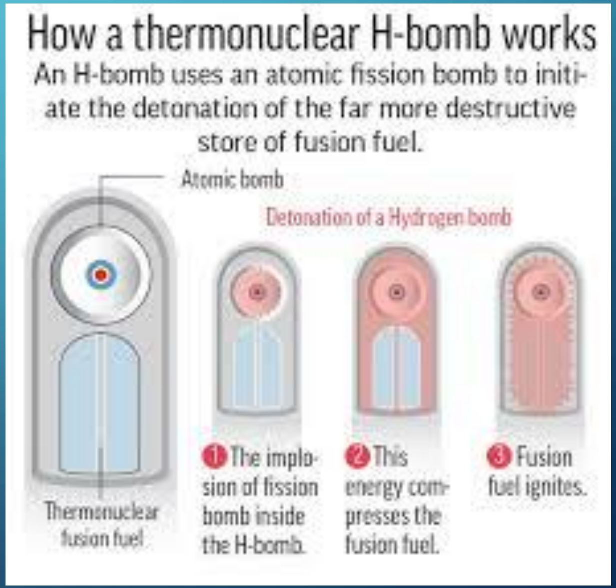
WHAT THIS IS NOT!



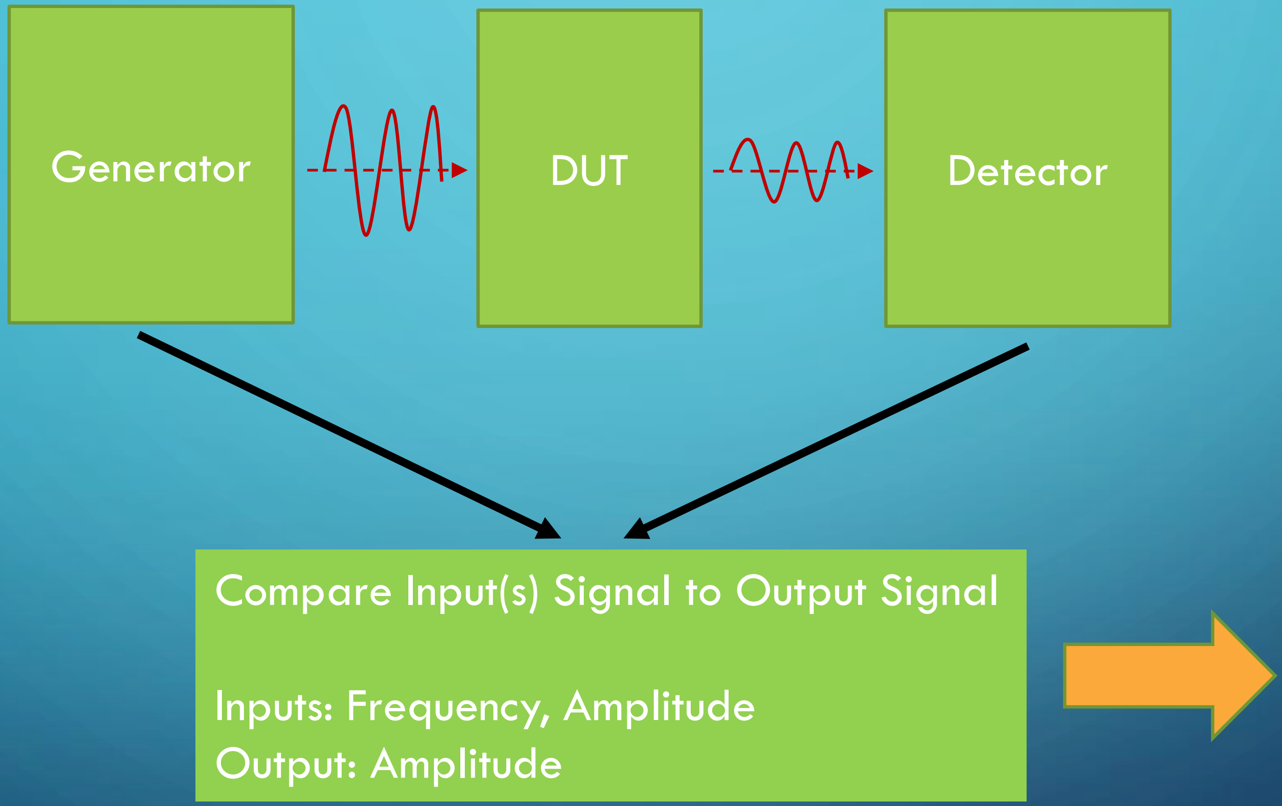


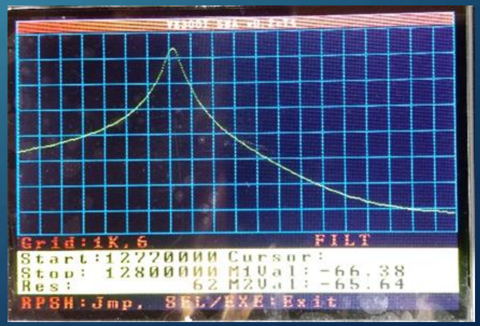






CONCEPTUAL DESIGN





FREQUENCY DEPENDENT ANALYSIS

Sorta

- Trying to understand the dependency on frequency.
  - i.e. How does the signal behave as a function of frequency
- Examples:
  - Is this cable any good? Does the cable behave differently with frequency?
  - How well does this QRP amplifier work? What frequency do I get peak performance?
  - Is my Low Pass Filter working as expected within the band of interest?
  - Is my antenna tuned properly?
  - etc...

NON-FREQUENCY DEPENDENT ANALYSIS

- We have a low power detector...lets measure signals
  - i.e. How strong is this signal?
- Examples:
  - How strong is the signal from this VFO, DDS, PLL oscillator?
  - How strong is the signal from this amplifier?
  - What is the SNR for this amplifier? (it may be possible)
  - etc...

FREQUENCY INJECTION

- We have a frequency generator…let use it as a signal source
  - i.e. inject a signal of known frequency and amplitude into something
- Examples:
  - Signal source to experiment with
  - A quick and dirty oscillator
  - Feed signal to a Mixer to modulate it.

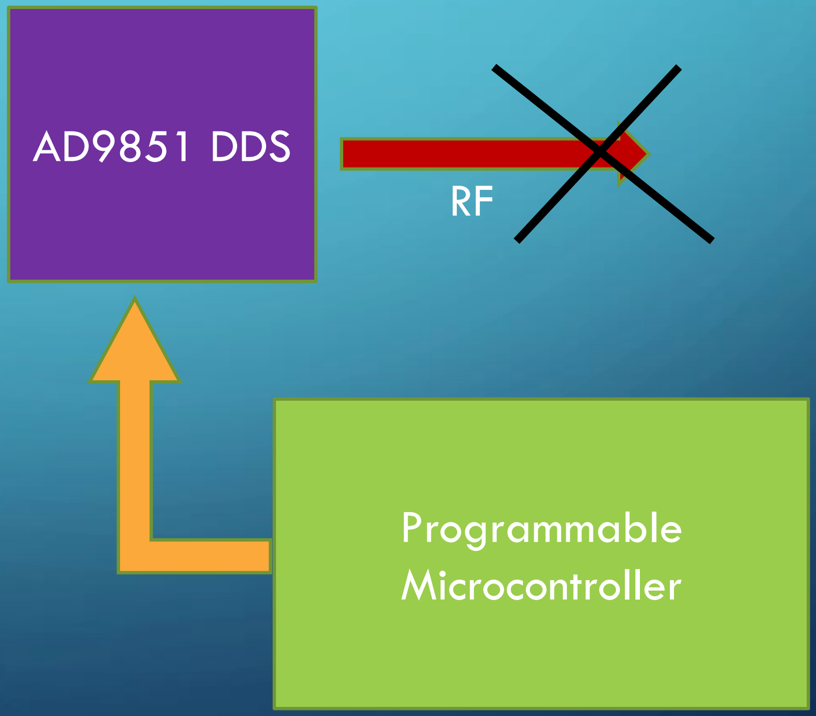
GENERATOR

AD9851 Module:

- AD9851 is a DDS Oscillator
- Uses a 30 MHz Crystal with 6x Multiplier (180 MHz)
- Advertised: 0-70MHz
- “After the 20-30MHz frequency harmonics increases, the waveform will be less and less clean”

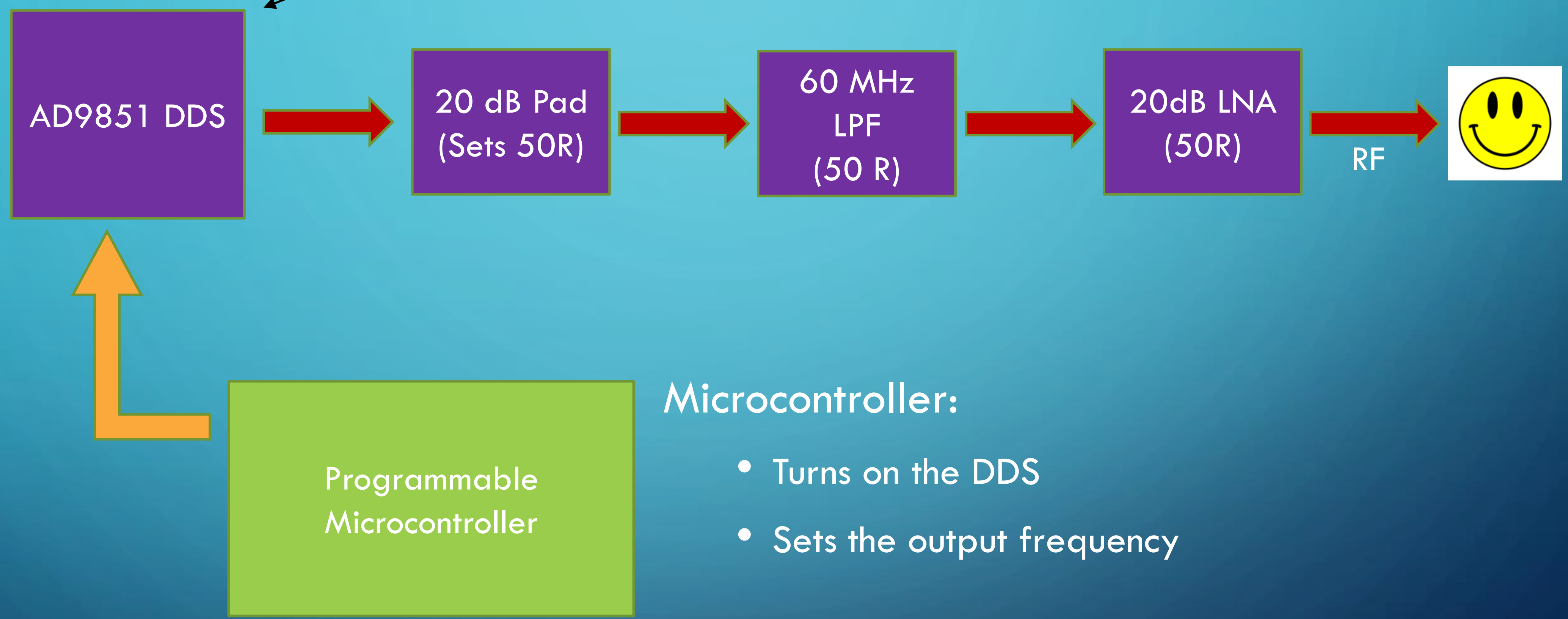
Issues:

- Wrong Impedance (not 50R)
- Impedance varies with frequency
- Signal Amplitude varies with frequency
- Signal Quality Deteriorates above 30ish MHz



GENERATOR

- Still Have a problem with roll off of signal amplitude with frequency.
- Compensate in software (Huh?...wait for it)



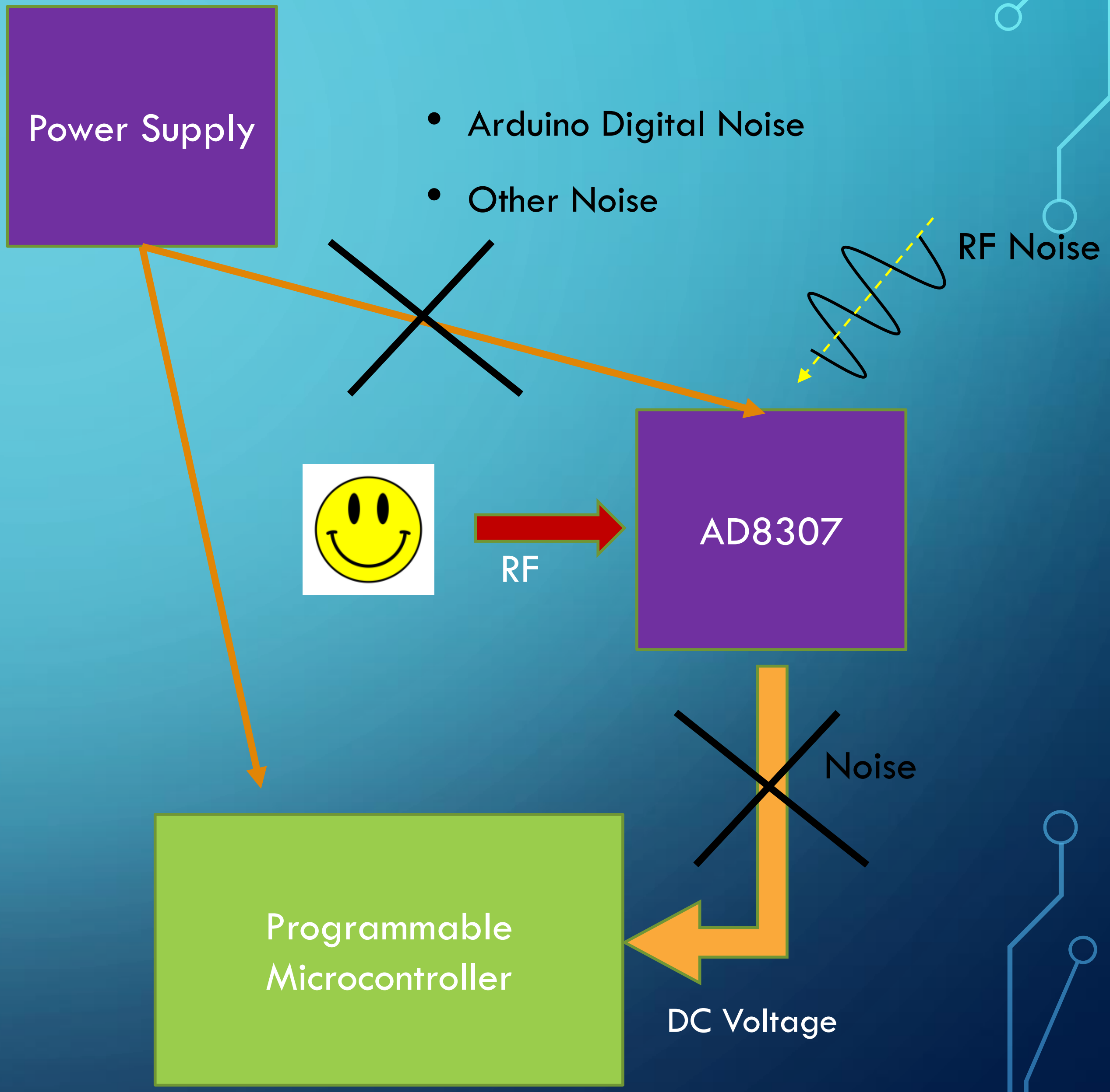
Microcontroller:

- Turns on the DDS
- Sets the output frequency

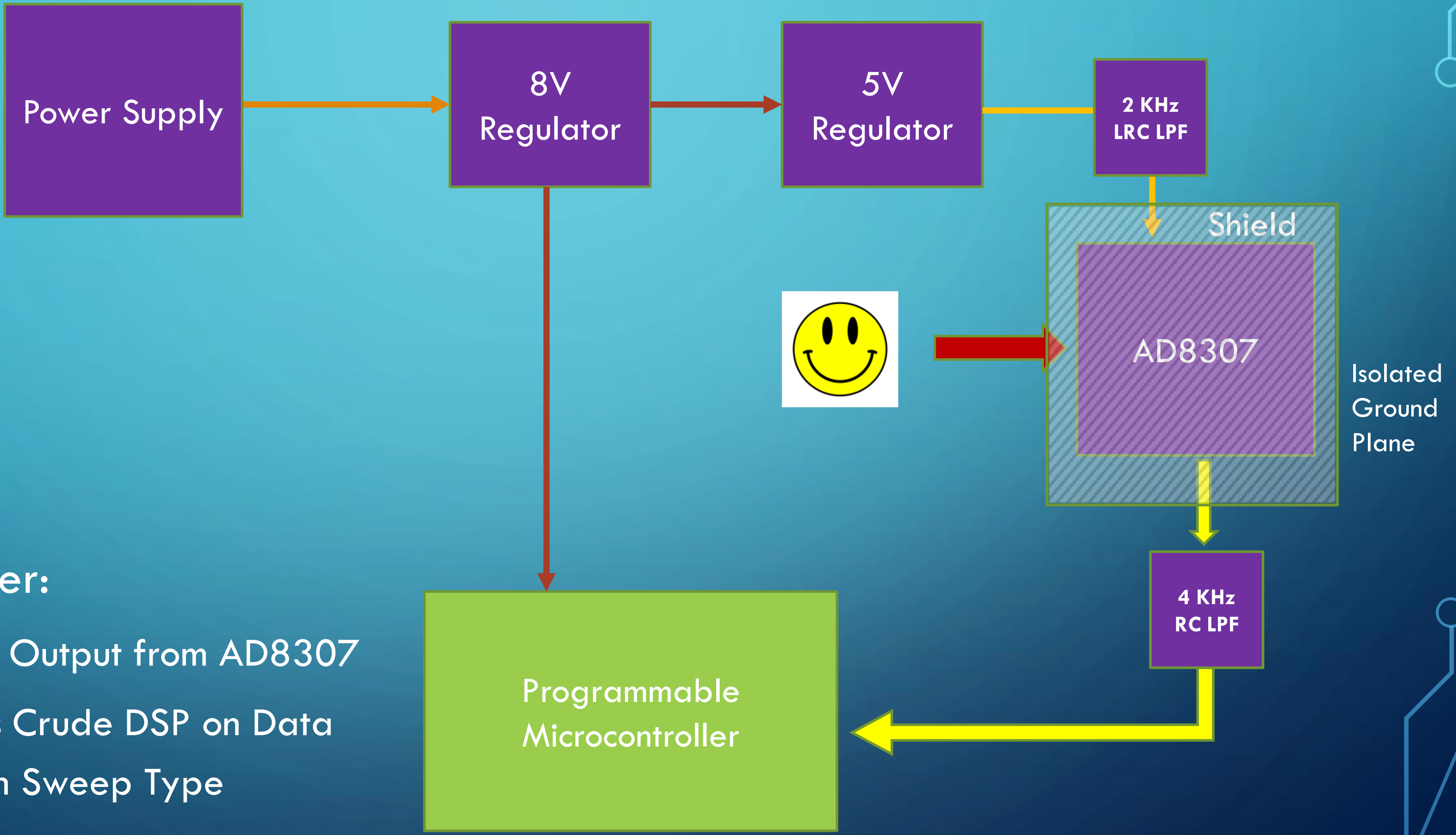
DETECTOR

AD8307 :

- Very Sensitive Detector (Logarithmic amplifier)
- Measure RF signals down to -70 or -80 dBm (Strong RF signal – e.g. S9)
- Outputs a DC voltage proportional to power of signal (i.e. dBm)
- Sensitive to power supply noise
- Sensitive to RF noise on traces



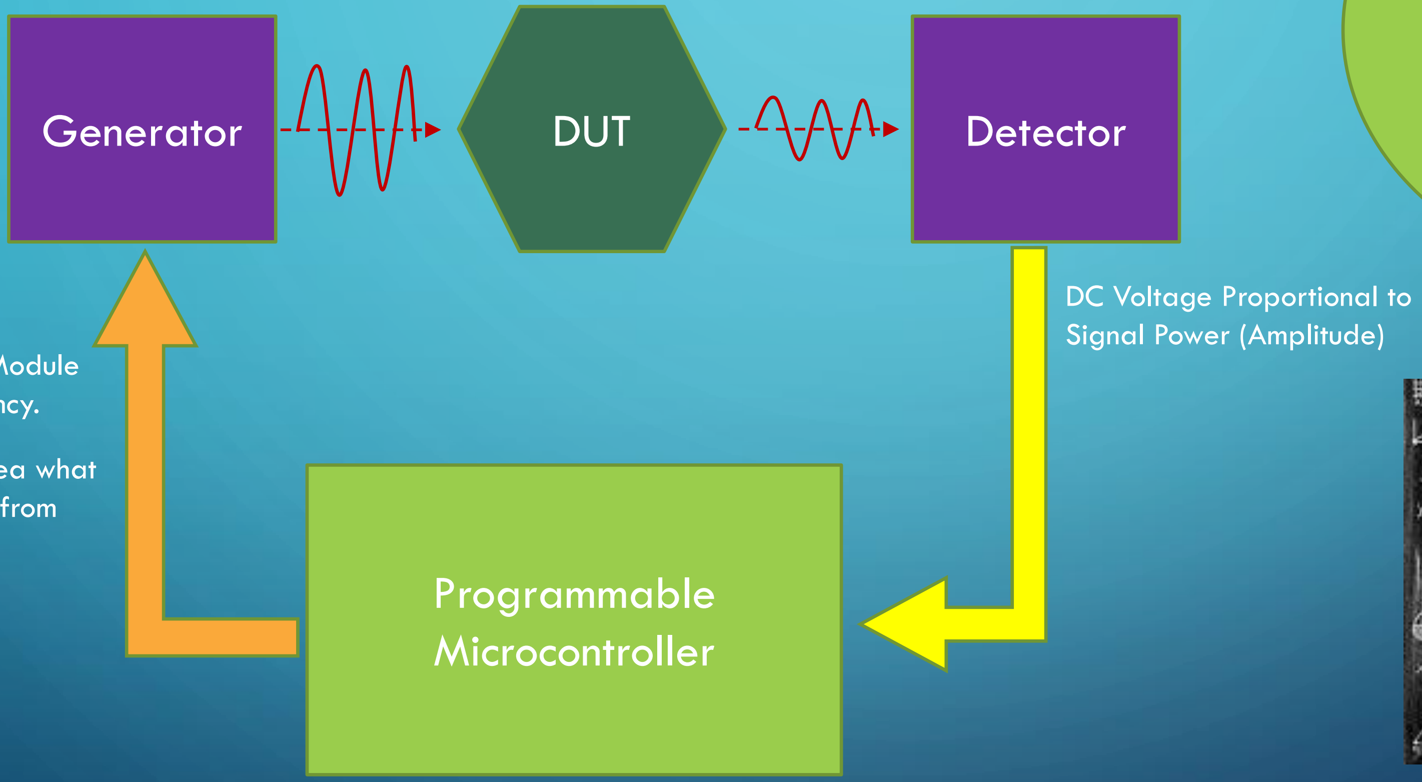
DETECTOR



Microcontroller:

- Digitizes Output from AD8307
- Performs Crude DSP on Data Based on Sweep Type

THE STORY SO FAR…



- Configures 9850 Module to output a frequency.
- The SNA has no idea what the signal strength from the Generator is

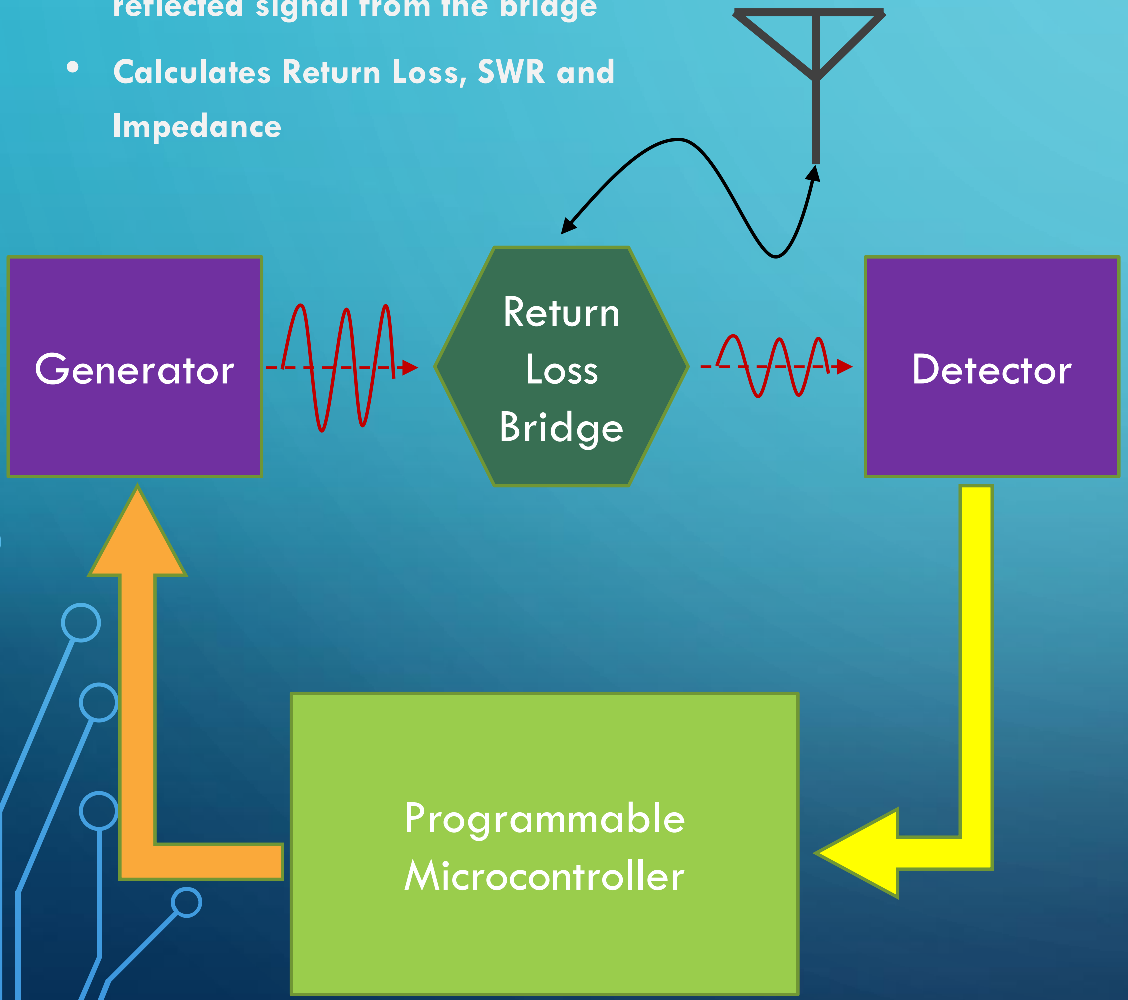
What's Wrong Here?

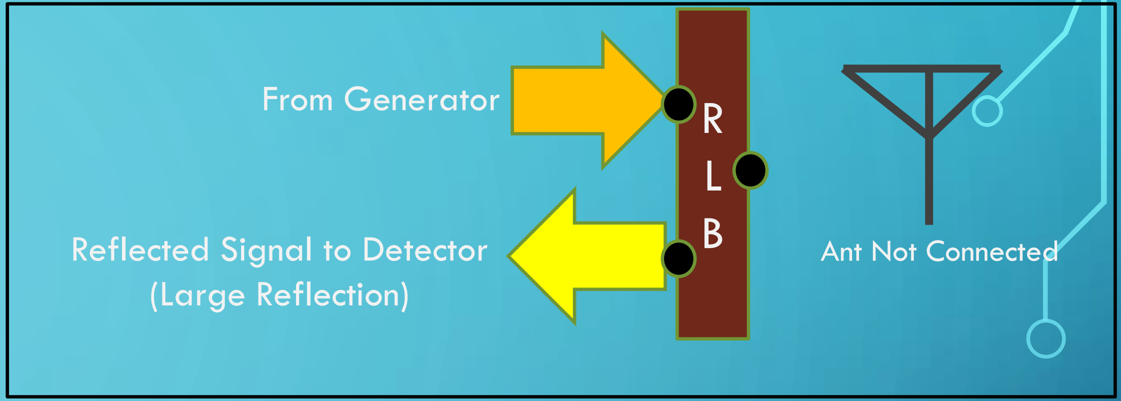
- **The Detector knows the signal strength from the DUT. So the SNA know this. Check!**
- **How does the SNA know how strong the signal is from the Generator?**

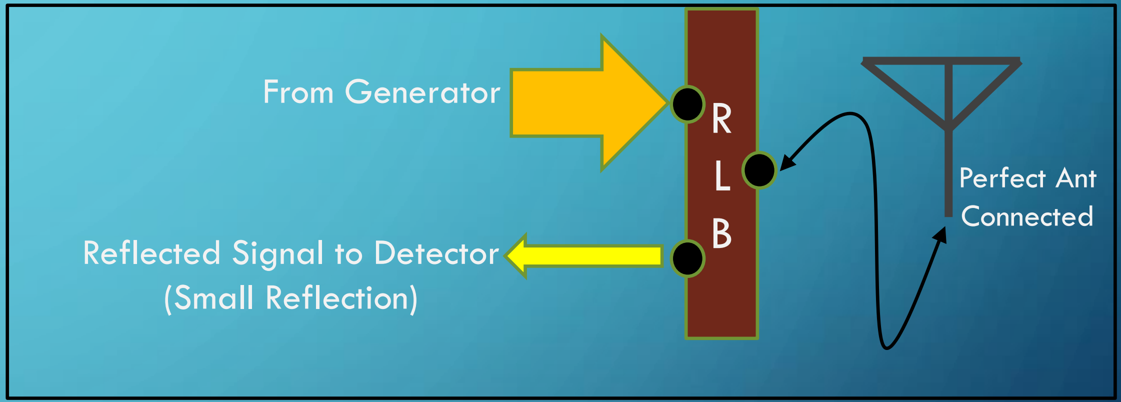
DUT: RETURN LOSS BRIDGE

Microcontroller:

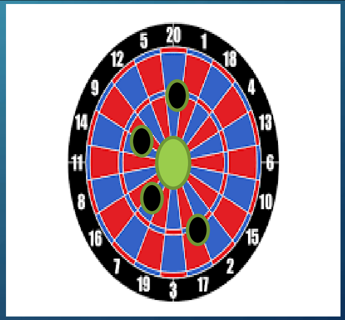
- **Sweeps through a set of frequencies**
- **Reads voltage from 8307 which is the reflected signal from the bridge**
- **Calculates Return Loss, SWR and Impedance**



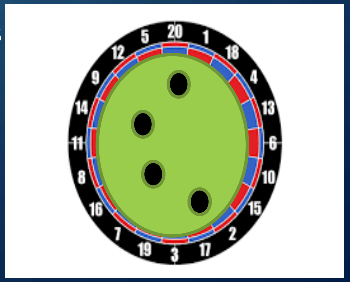




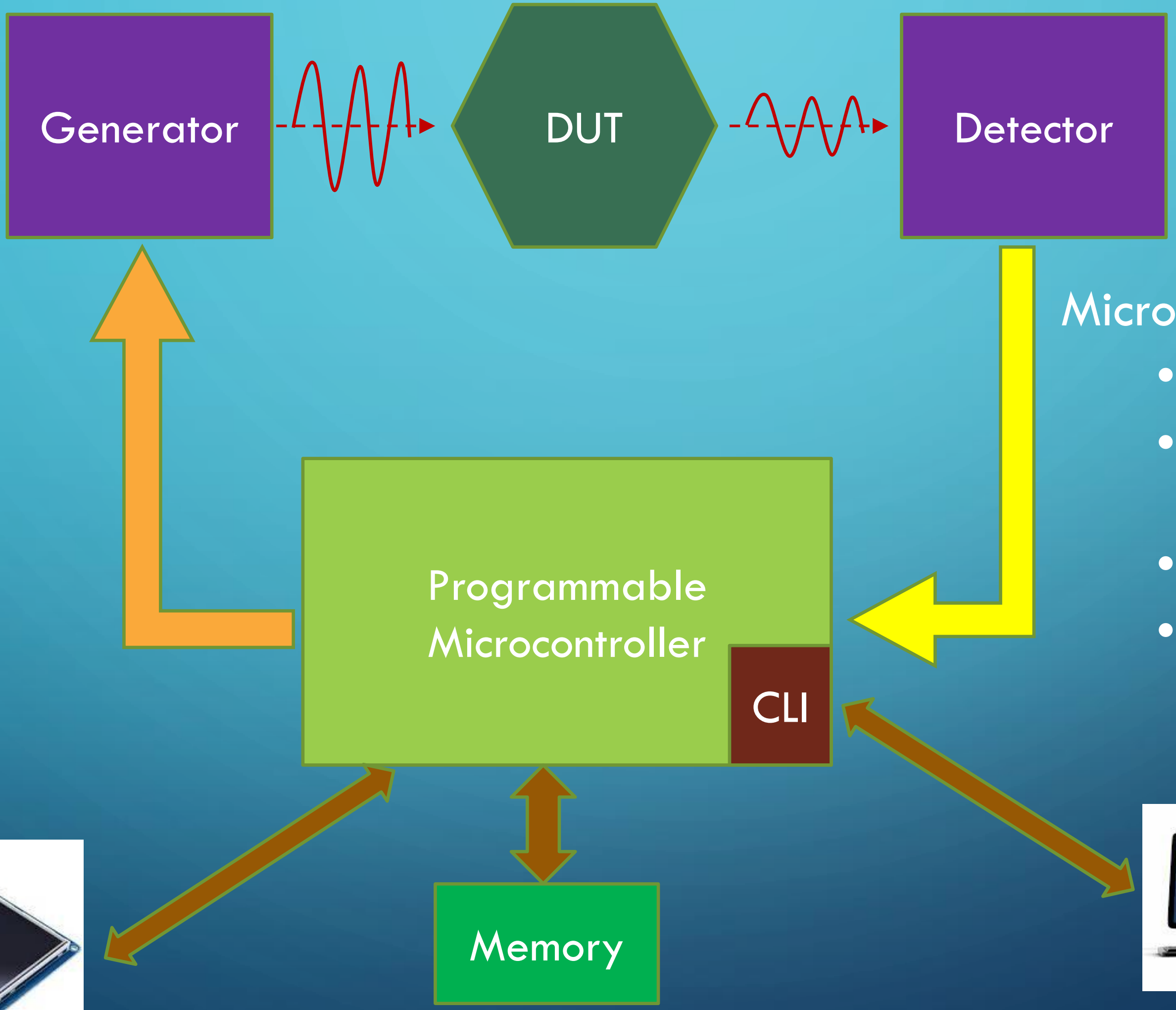
- **With no antenna connected "green" hole closed and every thing (black spots) bounces off.**
- **Low Return Loss.**
- **High Insertion Loss.**

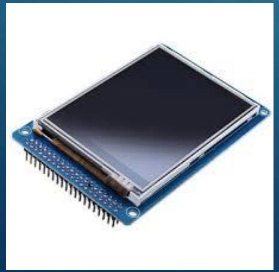


- **With a perfect antenna "green" hole is huge and every thing goes through and nothing bounces off.**
- **High Return Loss**
- **Low Insertion Loss**



ALL TOGETHER NOW





Microcontroller:

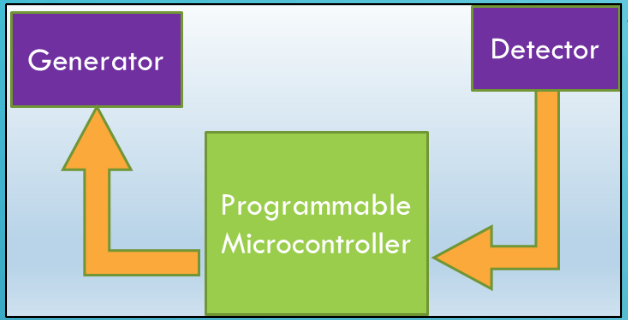
- Controlled via LCD and push buttons
- Save and recall data from sweeps to memory
- Can be controlled via PC
- Can export data to PC (e.g. for Excel)

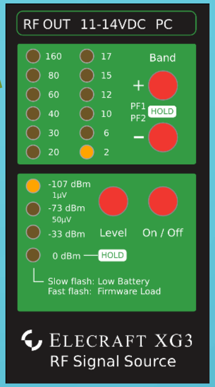
OK....NOW WHAT?

Calibration:

- The AD8307 output a voltage that we need to convert to dBm so we much teach the SNA about dBm (i.e. feed in known dBm values)
- The AD9851 uses a crystal with may be slightly off frequency spec
  - i.e. 29.9998 MHz instead of 30 Mhz.
  - Need to apply a correction to compensate for actual crystal frequency.
- We don't measure the signal strength of the AD9851 and cannot do any meaningful comparisons
  - We need to understand how the signal strength from the AD9851 varies with frequency

AD8307 CALIBRATION





Train the SNA to understand the AD8307

- Feed in two signal levels for comparison
- SNA compares the AD8307 output voltage to the signal level
- Formulates how to convert voltage to signal level

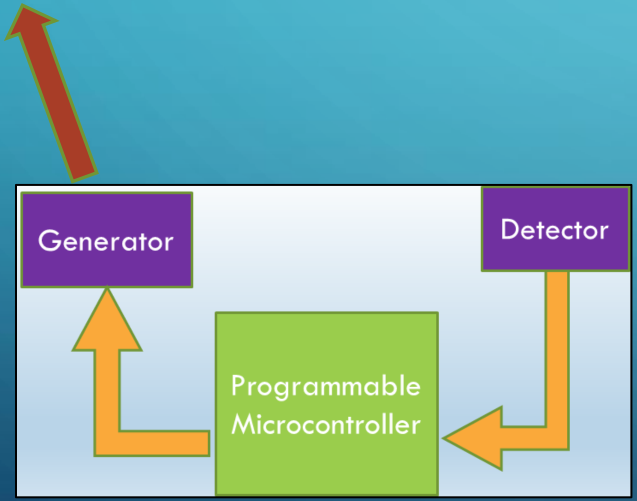
Signal Level	Voltage
0 dBm	4.01
-33 dBm	2.61

Slope = 42.51,
Intercept = -94.43

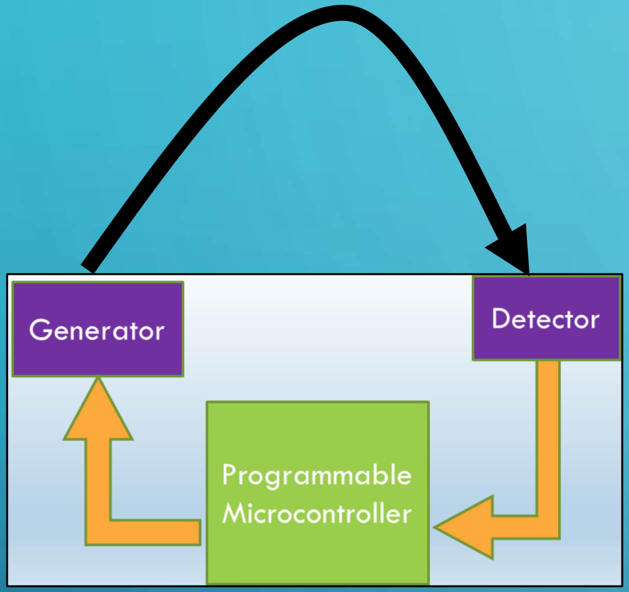
AD9851 FREQUENCY ACCURACY CALIBRATION

Train the SNA to compensate for actual AD9851 Module crystal frequency.

- Read the frequency from the SNA with a frequency counter
- Change compensation factor until desired frequency is present



SWEEP CALIBRATION: CHARACTERIZE OUTPUT FROM AD9851 MODULE



Train the SNA to understand how the AD9851 output varies with frequency.

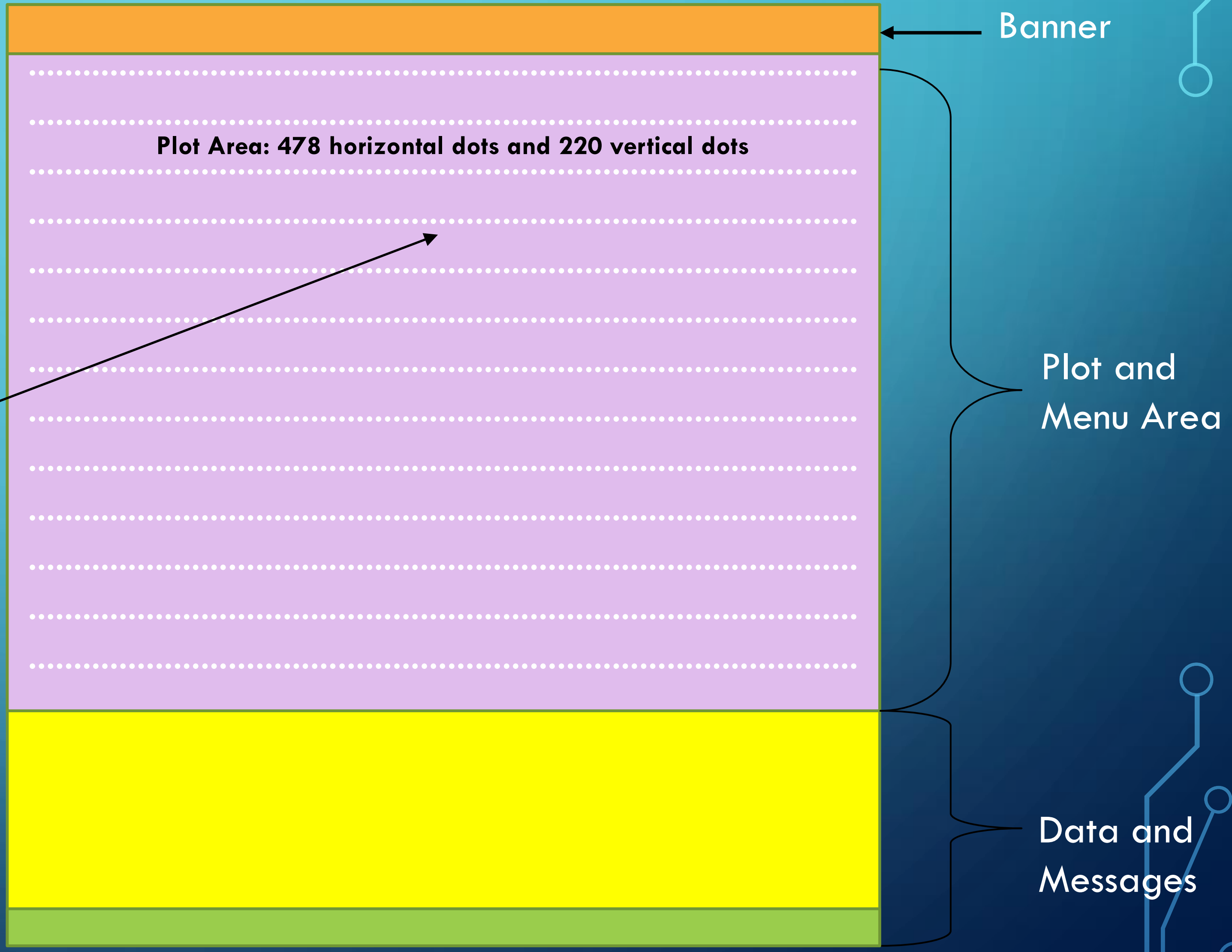
- Connect the AD9851 module directly to AD8307
- Change the frequency across entire supported frequencies (1 to 33 MHz)
- Store the values in memory for lookup

Frequency	Signal Voltage	dBm
1000 KHz	2.010	-9.0
1070 KHz	2.010	-9.0
1140 KHz	2.008	-9.1
1210 KHz	2.008	-9.1
1280 KHz	2.006	-9.2
1350 KHz	2.006	-9.2
1420 KHz	2.006	-9.2
1490 KHz	2.004	-9.2
1560 KHz	2.004	-9.2

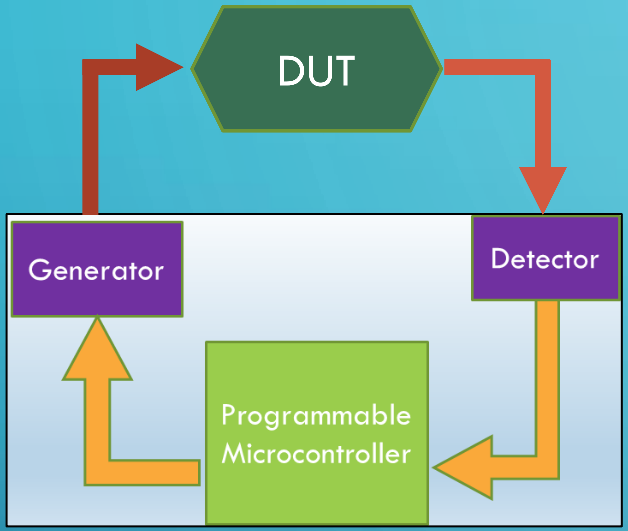
Create a lookup table from 1 MHz to 33 MHz and store it in memory

SWEEP RESOLUTION AND THE LCD

- **There is a plot area were the sweeps are displayed.**
- **The area is a fixed vertical and horizontal size**
- **The LCD is made up of dots called pixels. Each pixel can be on, off and a colour**
- **The LCD we use has 480 horizontal dots and 320 vertical does**
- **The plot area has 478 horizontal dots and 220 vertical dots**
- ***To make plotting easy, we only take 478 readings – one for each dot.***



DATA ACQUISITION



Microcontroller:

- User specifies start and end frequency
- Calculates frequency increment based on max 478 frequencies
  - E.g. From 1 MHz to 2 MHz,
  - increment is 1MHz/478=2092 Hz
  - SNA calls this the resolution
- Changes frequency by the resolution and read the output voltage from the AD8307.
- The ADC values is store in memory and converted to dBm using AD8307 Calibration

Frequency	ADC Value	8307 Voltage	Signal dBm
1000000	205	1.0	-51.9
1002092	225	1.1	-47.7
1004184	307	1.5	-30.7
1006276	410	2.0	-9.4
1008368	410	2.0	-9.4
1010460	369	1.8	-17.9
1012552	307	1.5	-30.7
1014644	184	0.9	-56.2

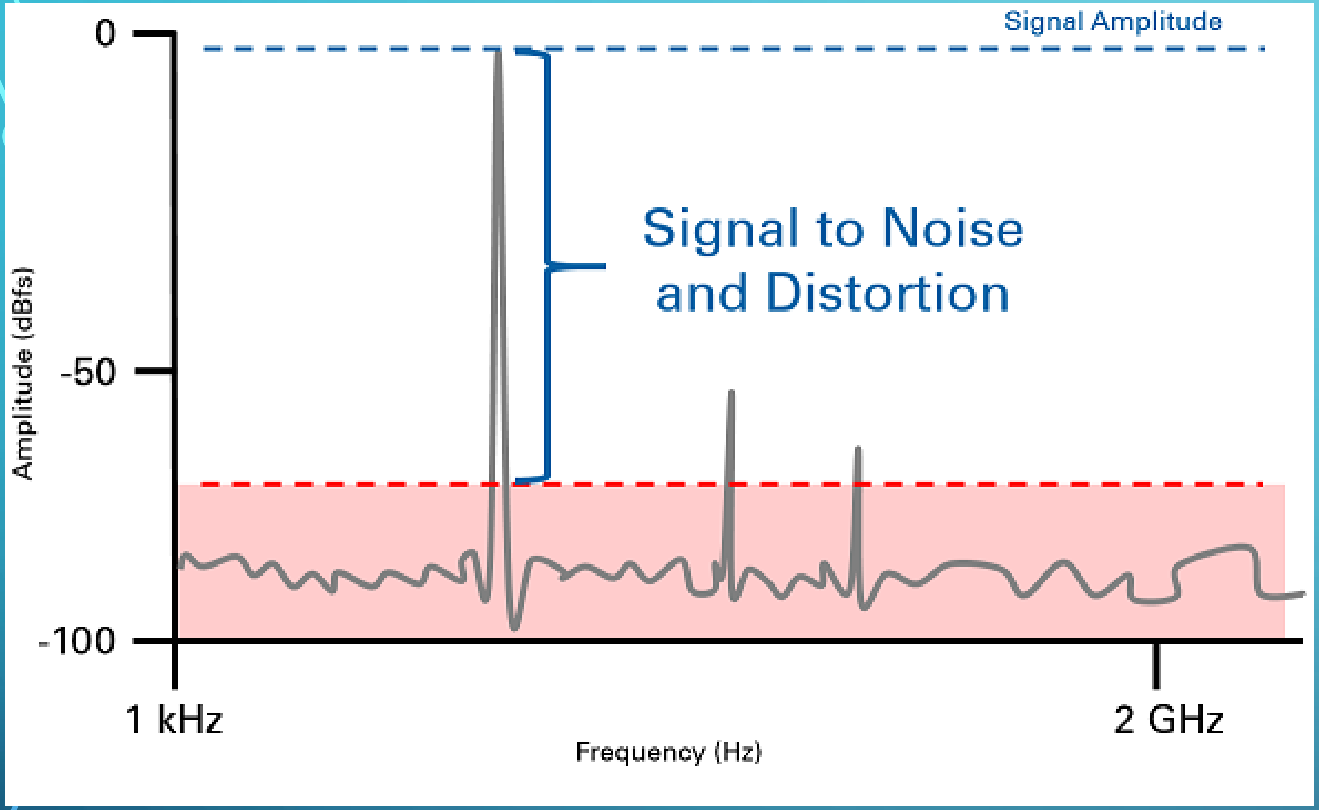
Table has 478 Values

A FEW CLOSING THOUGHTS...

A NORMAL CAT

DAVE'S CAT

HOW LOW CAN YOU GO?



What is the minimum SNR that allows the AD8307 to detect a signal accurately?

Datasheet: *The AD8307 has very high gain and a bandwidth from dc to over 1 GHz, at which frequency the gain of the main path is still over 60 dB. Consequently, **it is susceptible to all signals** within this very broad frequency range that find their way to the input terminal*

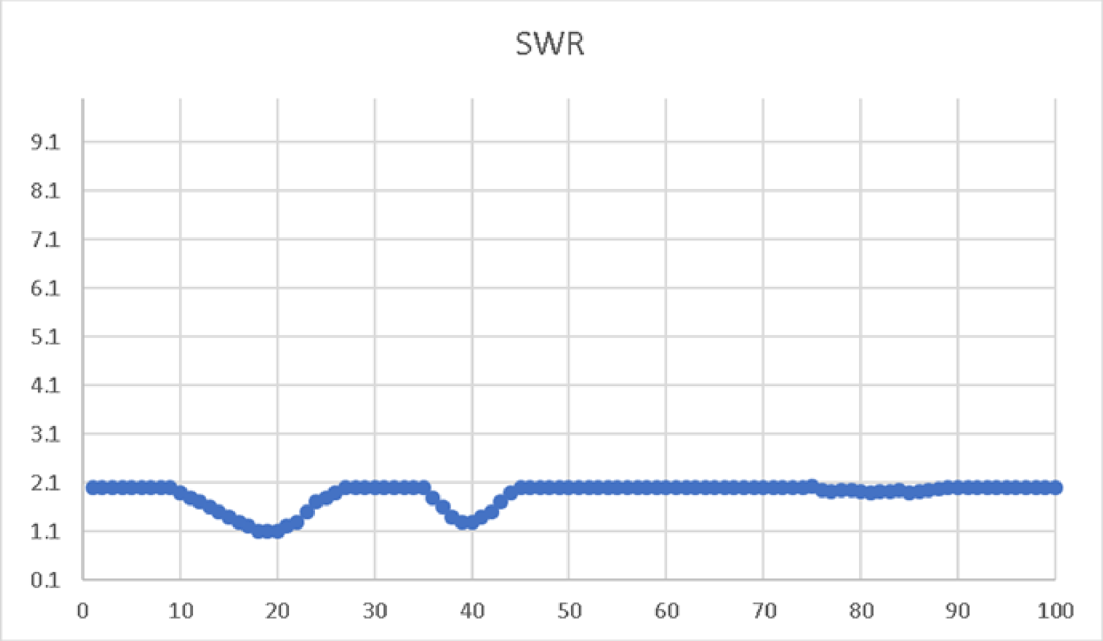
CALIBRATION ERRORS

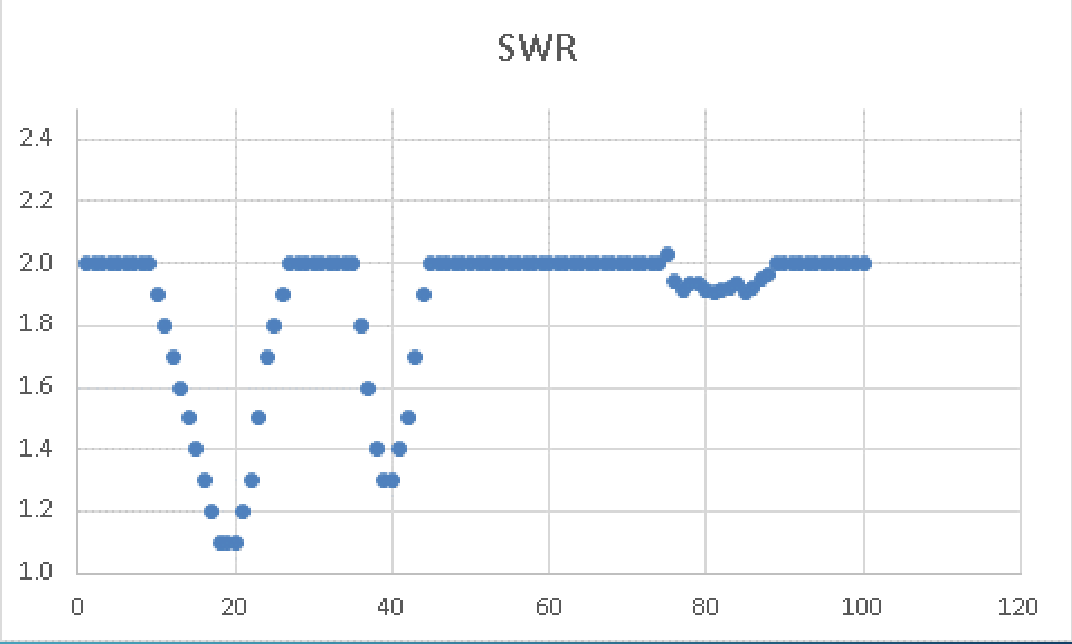
- **Green line** is the actual calibration line with no error
- **Red Line** the Higher Calibration Value is lower by 3 dB
  - -3 dBm instead of 0 dBm
- **Orange Line** the Lower Calibration Value is lower by 3 dB
  - -36 dBm instead of -33 dBm

- At +10 dBm error is about 3 dBm
- At -70 dBm error is about 5 dBm

- If both calibration values are off, then the error is worst.

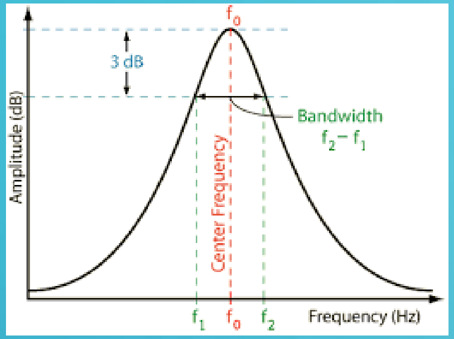
SCALING



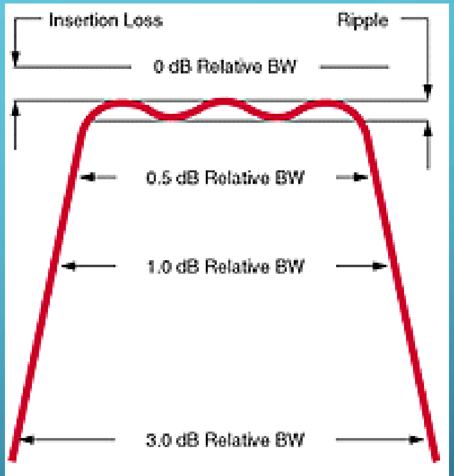


- No Scaling performed horizontally. Each of the 478 data point plotted
- Vertical plot scaled to get maximum view.
- Vertical scaling magnifies any noise/jaggedness

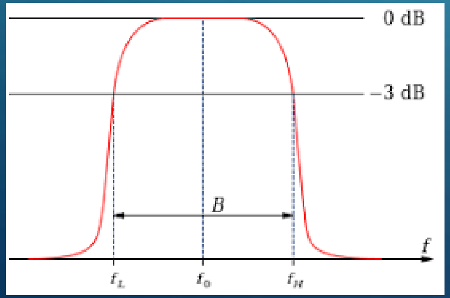
CRYSTAL AND 3DB SWEEPS



- The 3dB sweep is used to calculate crystal motional parameter using the crystal test fixture.
- It calculates the peak (i.e. largest dB) and then looks for -3dB points to calculate the -3dB bandwidth.

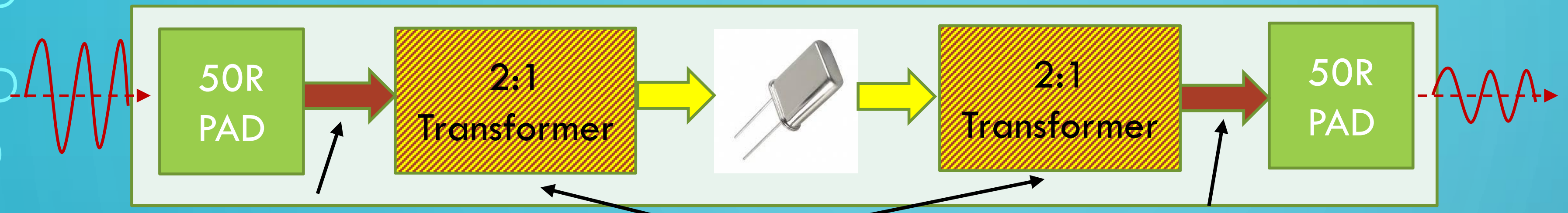


- If there is any ripple in the crystal bandpass, the 3dB sweep will generate erroneous results.
- The curve must be "well behaved"



- If the curve is flat this is ok
- Probably do to response of crystal
- i.e. sweep resolution is too small

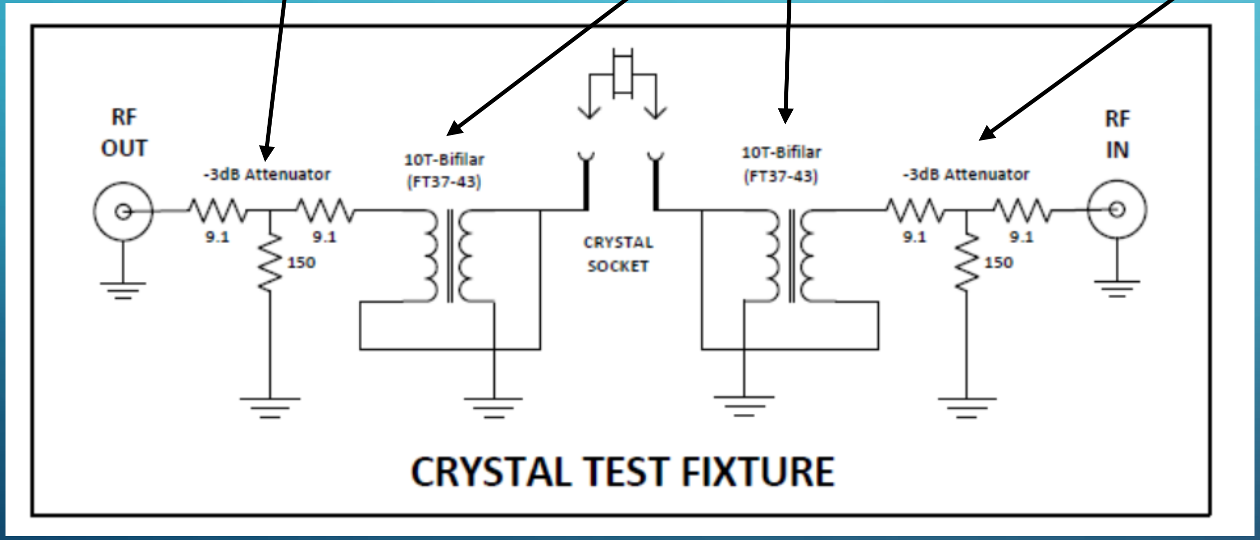
CRYSTAL CALIBRATION: THE "PETER" PERTURBATION



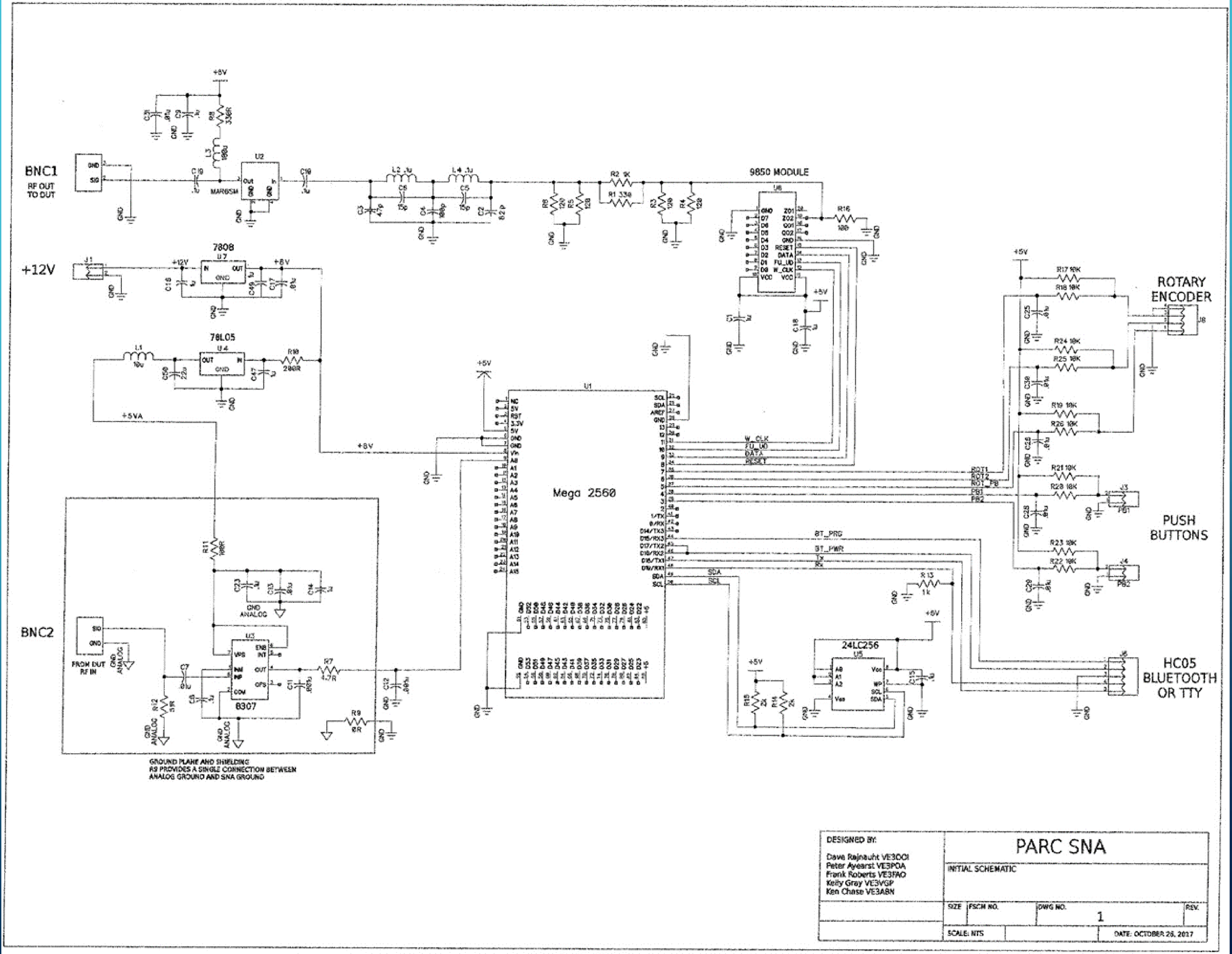
Forces 50R

Transforms 50R to 12.5R

Forces 50R



- Use two -3dB pad totalling -6dB insertion loss
- By default SNA adds back 6dB to 3dB sweep to calculate real insertion loss
- More accurate is sweep the test fixture with crystal shorted out to measure "actual" extra insertion loss resulting from attenuator pads and transformer losses.
- Hard code the result into SNA
- Detailed in Advance Guide



BNC1
RF OUT TO DUT
MAR6SM
+12V
7808
78L05
+5VA
+8V
BNC2
FROM DUT RF IN
8307
GROUND PLANE AND SHIELDING
R9 PROVIDES A SINGLE CONNECTION BETWEEN
ANALOG GROUND AND SNA GROUND
9850 MODULE
Mega 2560
ROTARY ENCODER
PUSH BUTTONS
24LC256
HC05 BLUETOOTH OR TTY
DESIGNED BY:
Dave Rajnauht VE3OOI
Peter Ayearst VE3POA
Frank Roberts VE3FAO
Kelly Gray VE3VGP
Ken Chase VE3ABN
PARC SNA
INITIAL SCHEMATIC
SIZE
FSCM NO.
DWG NO. 1
REV.
SCALE: NTS
DATE: OCTOBER 26, 2017