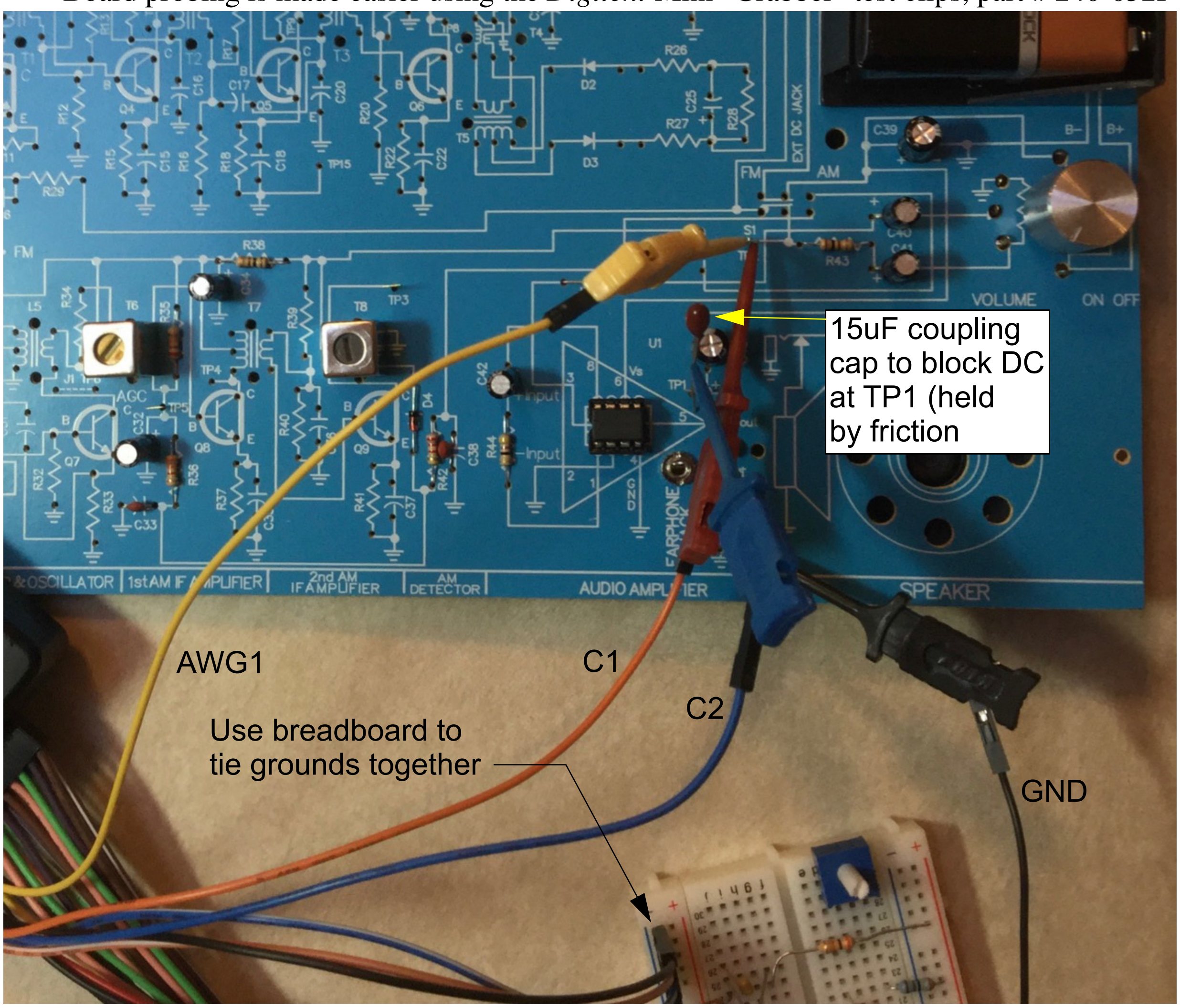
ECE 3001 Capstone: Elenco Superhet 108

This document walks through testing of the Elenco Superhet 108 board using the Analog Discovery in place of the test procedures found in the radio kit manual. The manual assumes a volt-ohm meter (VOM) is available along with a scope and signal generator.

Section 1A: AudioLM386 Audio Amplifier

The first board assembly task is to build up the LM386 audio amplifier. The instructions for this are found on manual pages 7–9. Testing is composed of static measurements (current draw and voltage), and dynamic measurements (gain at 400 Hz and 3dB bandwidth, plus distortion).

- Board probing is made easier using the *Digilent* Mini "Grabber" test clips, part # 240-052P[1]

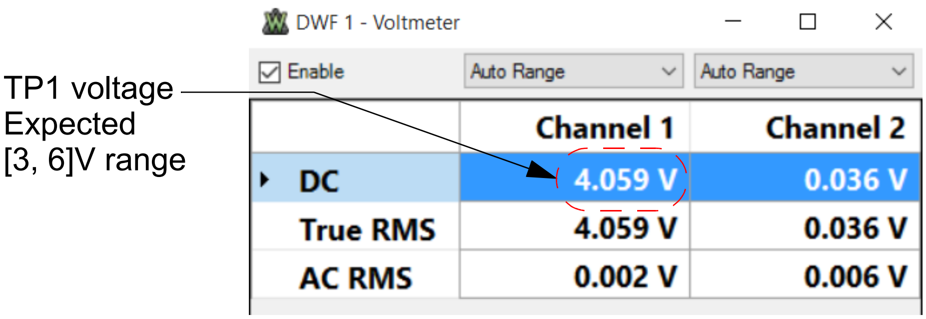


1. http://www.digilentinc.com/Products/Detail.cfm?NavPath=2,393,1073&Prod=MINI-GRABBERS. The price is rather high at $14.99 for six.

Static Measurements

The requested static measurements are the idling current draw from the 9v battery with no signal applied to the amplifier input. Secondly, the DC bias present at the amplifier output when no input is applied.

- The current draw was measured using a Fluke DVM to be about 4mA
  – No easy way to do this with the analog discovery, so move on the output bias test
- Using the Analog Discovery voltmeter the output bias voltage with no input signal is:

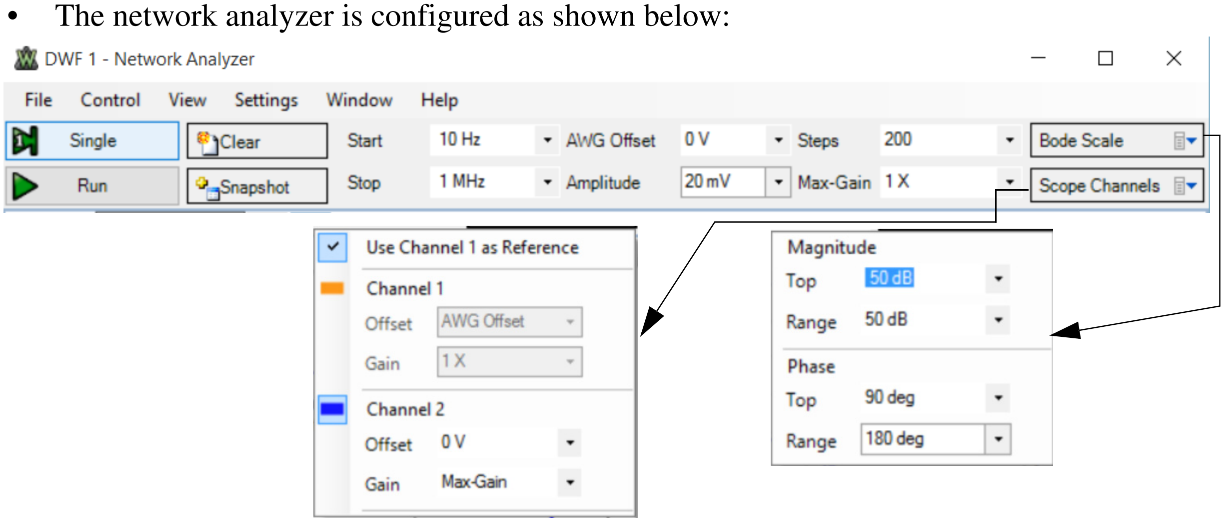


  – This result falls into what is expected for the LM386 operating with a 9V supply

Dynamic Measurements

The requested fixed frequency gain measurement and 3dB bandwidth measurement is combined into a single measurement using the Analog Discovery network analyzer.

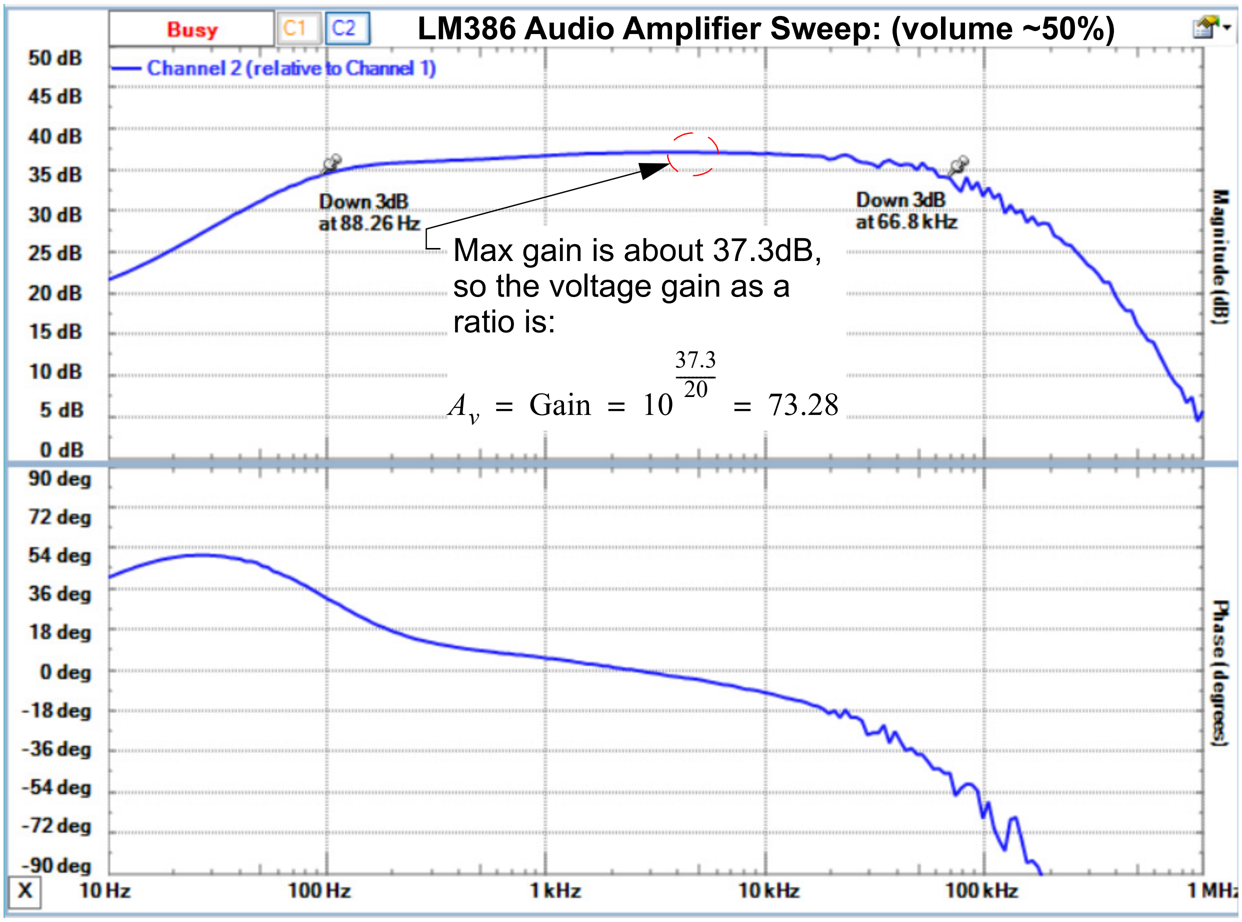
- The manual describes making a fixed frequency gain calculation using a fixed frequency of 400 Hz
- The voltage gain as a ratio is obtained from the network analyzer result
- The network analyzer is configured as shown below:



- The volume level on the radio board is at just over 50%
- **Note**: As the amplifier frequency is obtain you will hear the measurement taking place since

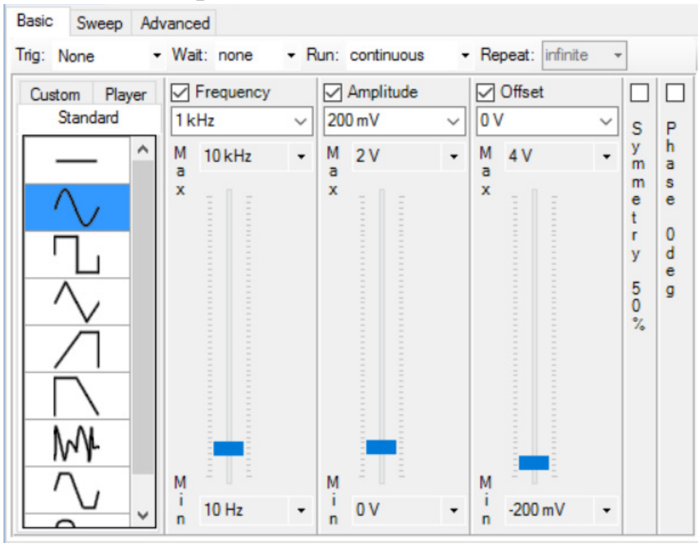
the speaker output is enabled by default

- The results of the sweep from 10 Hz to 1 MHz is the following:



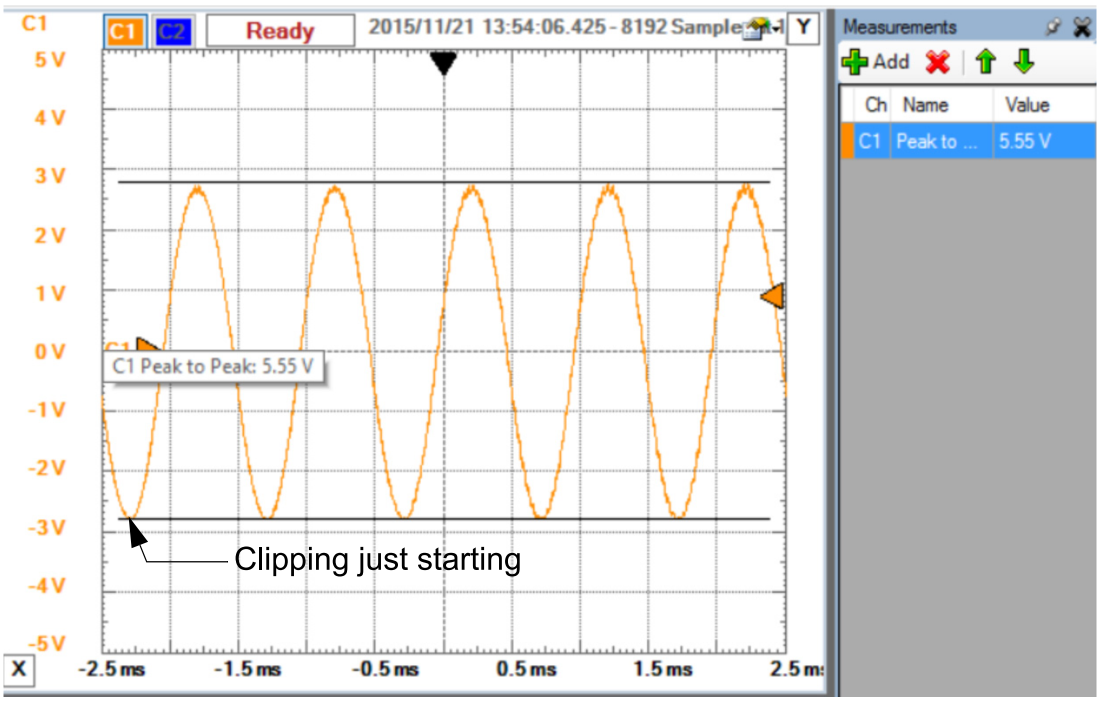
- The measured 3dB bandwidth is thus $66.8 - 0.08826 = 66.7\,\text{kHz}$
- For the distortion measurement follow the instruction and observe the clipped output on the scope

- Set the input at TP2 follows:



- To remove the DC at TP1 run a wire from TP1 to a breadboard and pass the signal through a coupling capacitor, say 10µf with a 47kΩ resistor to ground
- Attache an Analog Discovery scope channel to the high side of the 47kΩ resistor

- Raise the volume level until clipping just begins to appear:



  – The peak-to-peak as clipping begins is 5.55Vpp

- The $V_{\text{rms}} = V_p / \sqrt{2} = 1.962\text{ V}$
- The power delivered to the 8Ω speaker is

$$P_{\text{out}} = \frac{(1.962)^2}{8} = 481.2\text{ mW} \tag{1}$$

Efficiency

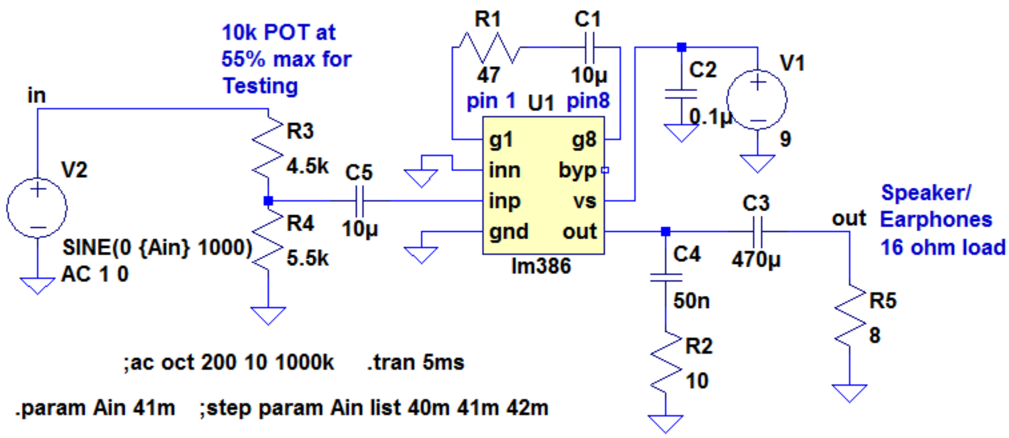
This step requires a DC current measuring instrument. This is available in the lab bench-top, but the needed cables are not in your tool box.

- This measurement is not made

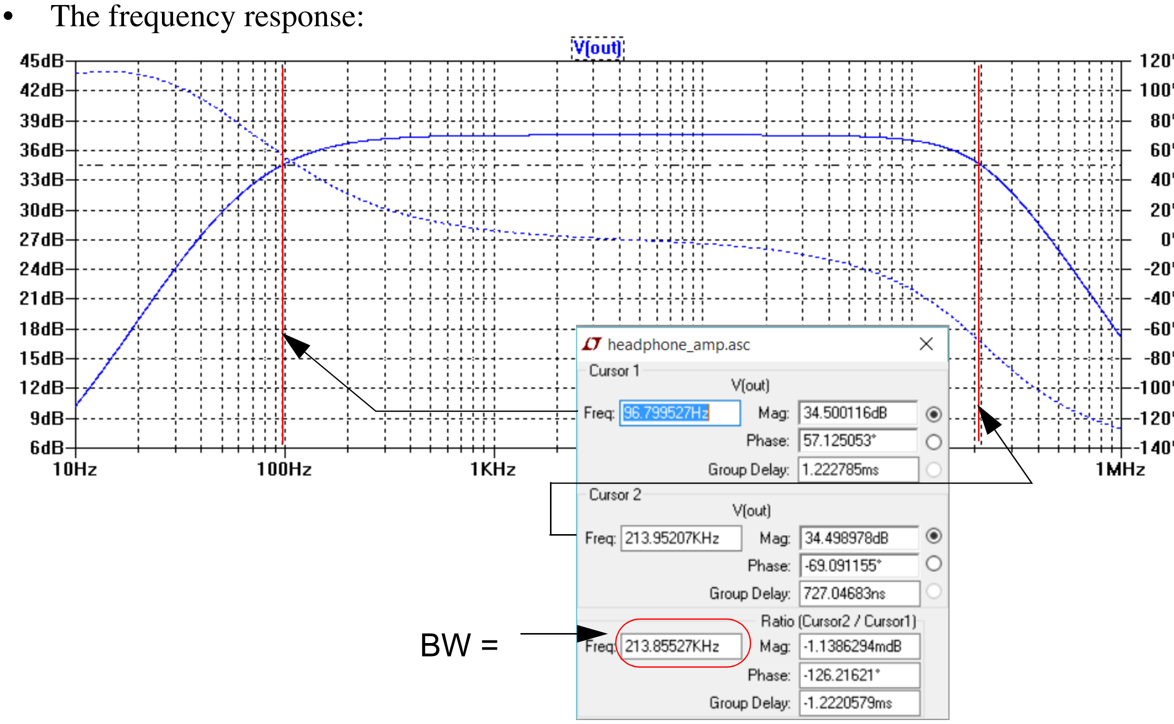
LTspice Model

It is interesting, although not required, to compare the measured amplifier results with the LTspice model discussed in the class notes.

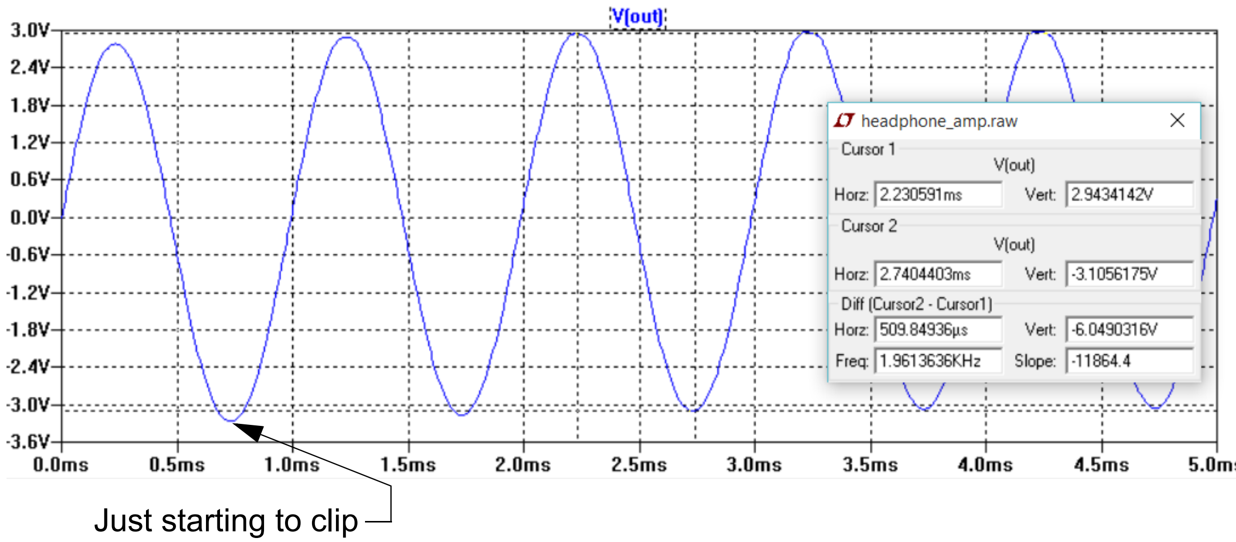
- Consider the following schematic:



- The static current draw from the 9V source is 16.1mA, much higher than actually measured
- The output bias voltage is 5.27V, higher than measured
- The frequency response:



- The gain, midband is, 37.55 dB, with the simulated 10k POT set at 55% of maximum gain
  - As a ratio $A_v = 75.42$
- The clipping measurement:



- From the LTspice measurements, $V_{pp} = 6.05\text{ V}$, so

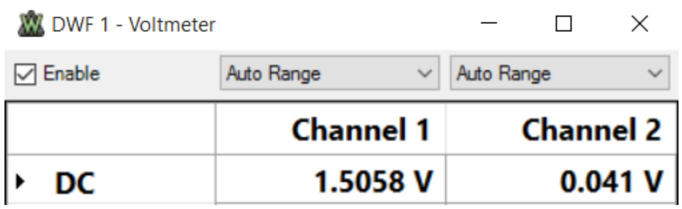
$$P_{out}^{sim} = \frac{(3.025/\sqrt{2})^2}{8} = 571.9\text{ mW} \tag{2}$$

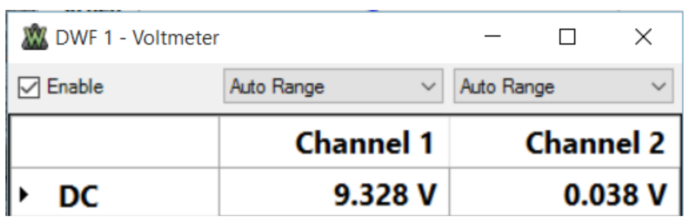
Section 2: AM Detector and AGC Stage

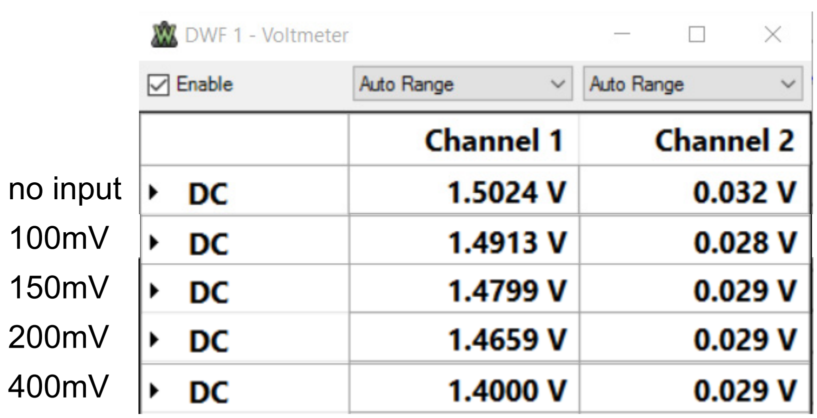
Here there are both static and dynamic measurements. First the AGC voltage is measured and then T8 bias is measured.

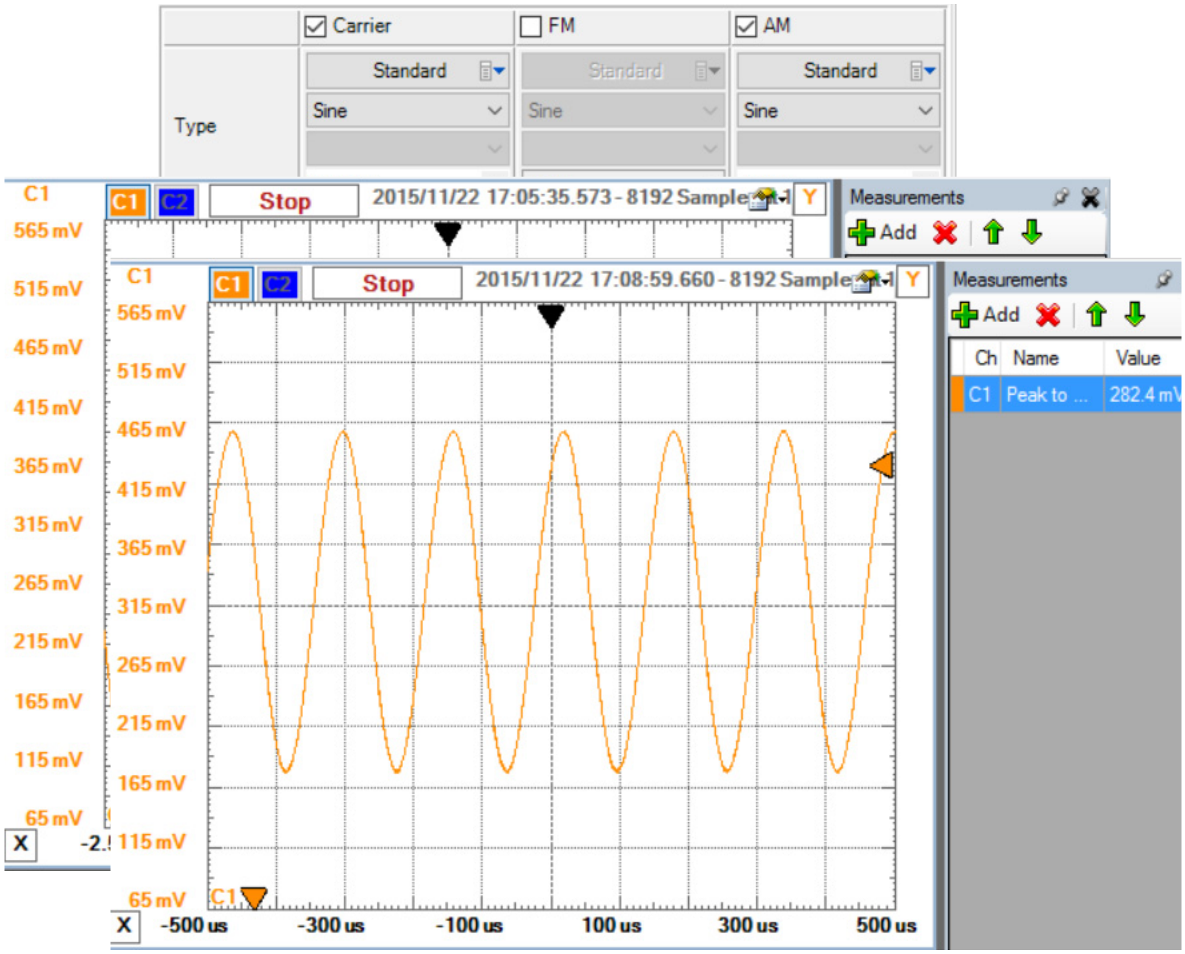
Static Measurements: AGC Zero Signal Bias

- At TP5 the bias voltage set up for automatic gain control (AGC) is verified:









1 kHz then 6 kHz

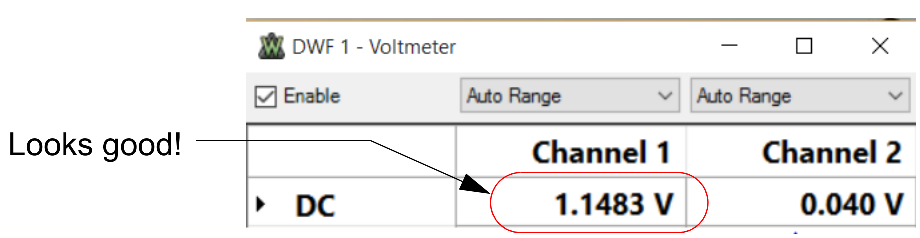
Section 3: Second AM IF Amplifier

What

Static Measurements

Measure the emitter voltage of Q9 to see if is close 1.0V

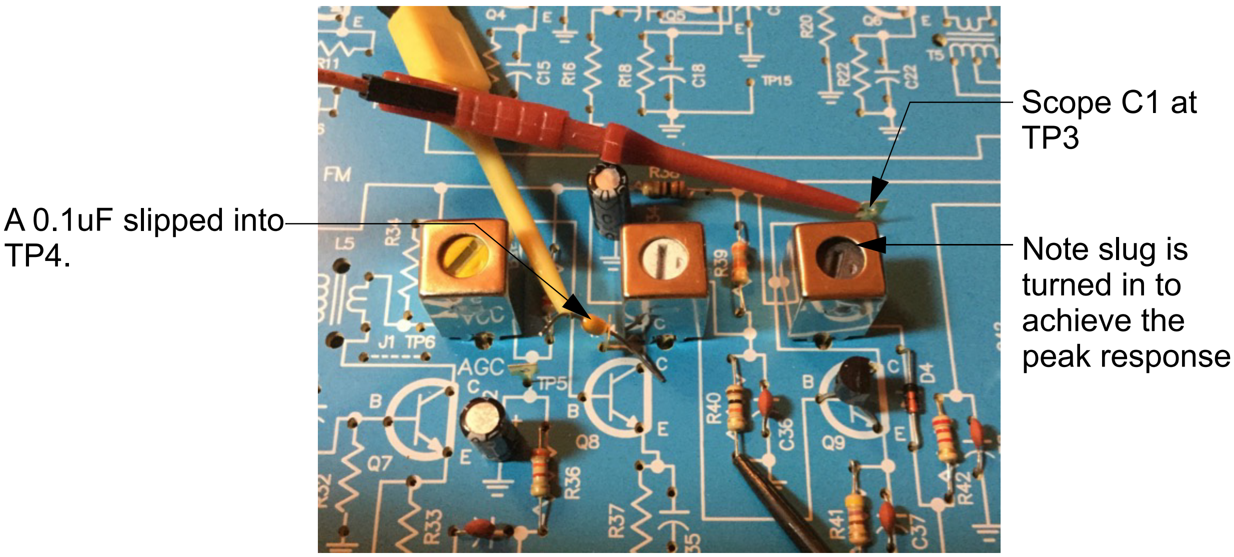
- We use Channel 1 of the voltmeter:



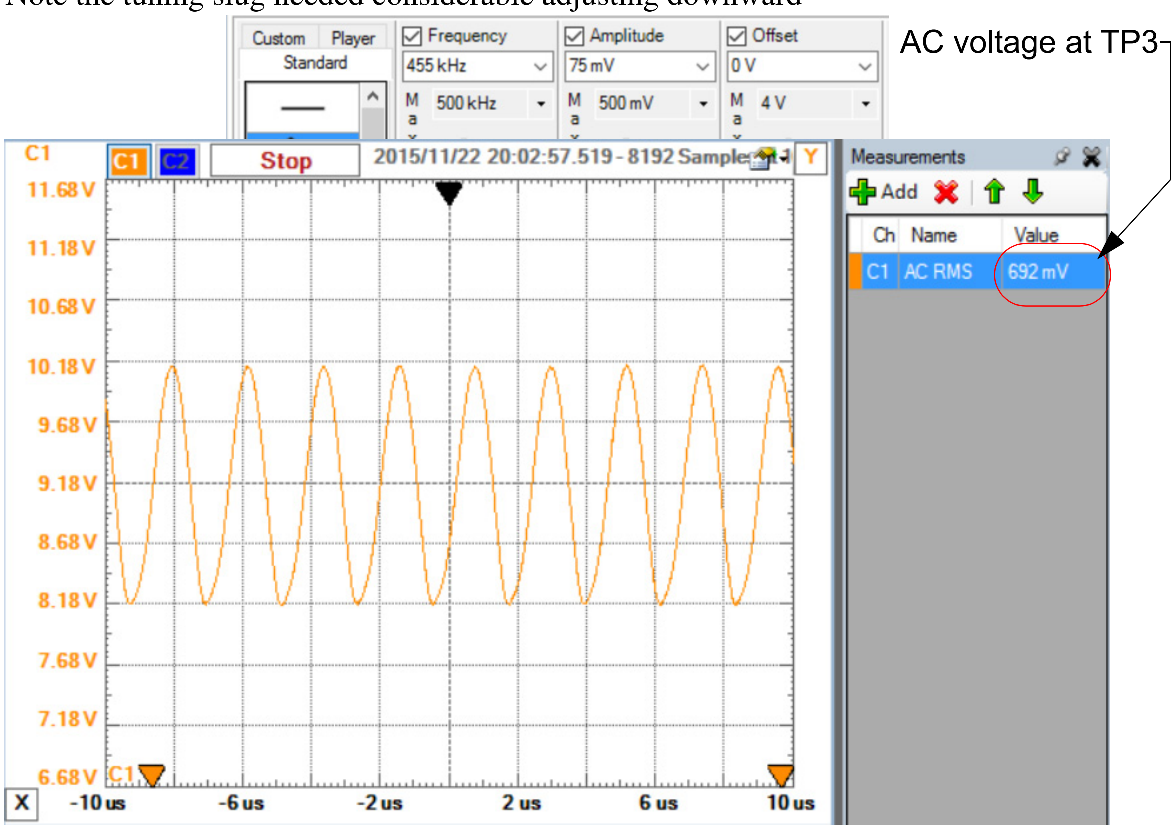
Dynamic Measurements: AC Gain

For this section there is a static measurement of Q9 bias, then tuning the IF transformer T8 and measuring its bandwidth at 455 kHz.

- AC Gain and T8 Transformer Peaking
- The input from AWG1 is attached using a 0.1 μF cap (0.001 OK too) and the scope channel C1 is attached to TP3

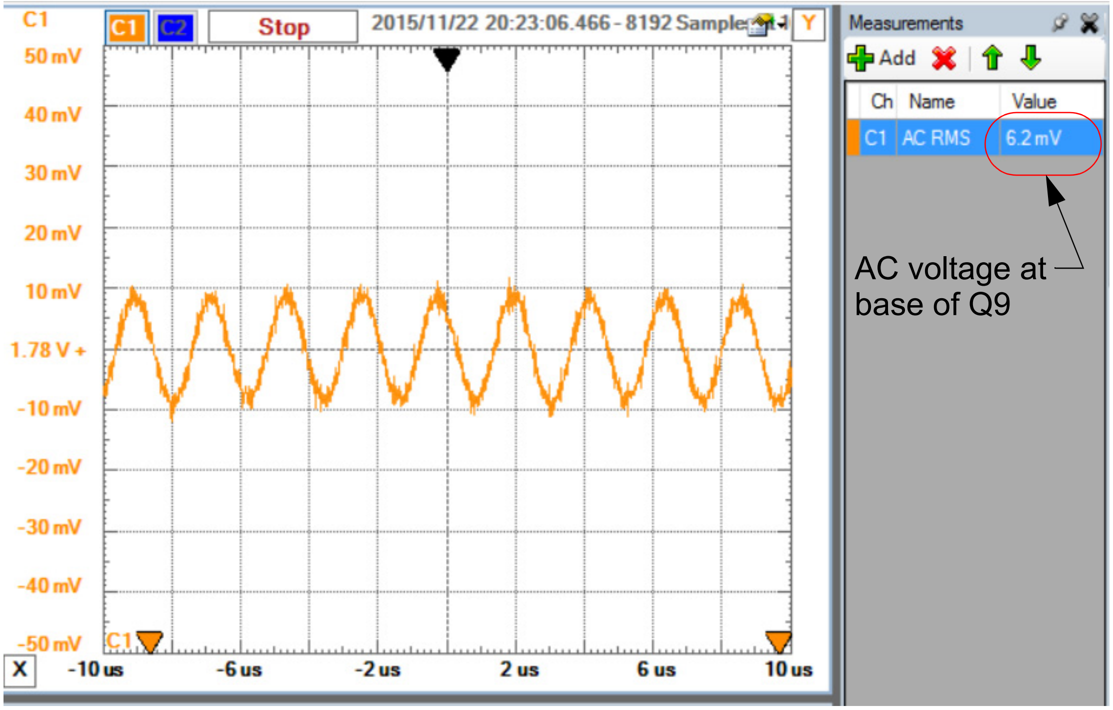


- Note the tuning slug needed considerable adjusting downward



- Hopefully this is OK, will find out more in later stages of receiver alignment

- **Voltage Gain**: Moving to probe at the base of Q9 and verify the amplifier gain:



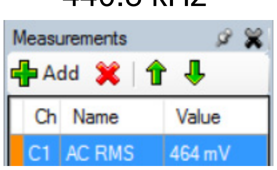
- The voltage gain is

$$A_{v,\,Q9} = \frac{692\text{mV}}{6.2\text{mV}} = 111.6 \tag{3}$$

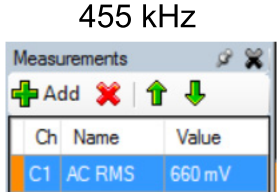
Good as greater than 100 is what is expected

- **Bandwidth**: Reconnect the scope to TP3 and peak the T8 if needed
- Next adjust the generator frequency below and then above 455 KHz to determine the approximate 3dB (0.707 point) bandwidth
- We will again use the AC RMS measurement capability of the scope to make the measurements
  - We start with the 455kHz peak reading of 658mV RMS (a bit different than before, but T8 is adjusted to get the peak again, just the same)
  - Tune the frequency below 455 kHz until the RMS voltage falls to $660 \times 0.707 = 466.7\text{mV}$; the frequency is 440.8 kHz
  - Similarly tune the frequency above 455 kHz until the RMS voltage falls to 466.7mV; the frequency is 470.7 kHz

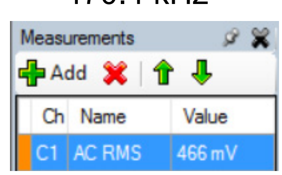
440.8 kHz



455 kHz



470.4 kHz



- The 3dB bandwidth is thus

$$BW_{T8} = 470.4 - 440.8 = 29.6 \text{ kHz} \tag{4}$$

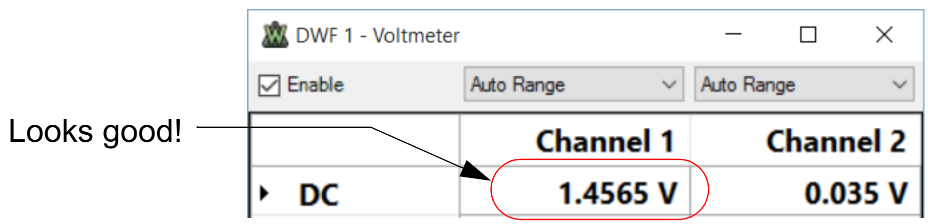
- The measured bandwidth is twice the value expected, but there is concern that the Analog Discovery scope is causing excessive capacitive loading, so this likely reduced the Q and hence increased the bandwidth; move on

Section 4: First AM IF Amplifier

For this section there are again static measurements of voltage and current, AC gain and observation of the AGC action.

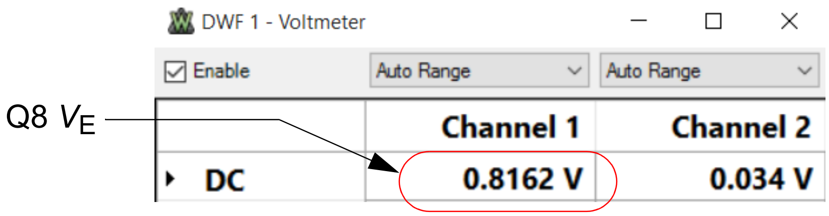
Static Measurements: Q8 Bias

- Measure the base bias voltage on Q8, expect approximately 1.5V:



- Measure the emitter current of Q8 by first measuring the emitter voltage, then infer the current using

$$I_E = \frac{V_E}{R_{37}} = \frac{0.8162\text{V}}{1000\Omega} = 0.86\text{mA} \tag{5}$$



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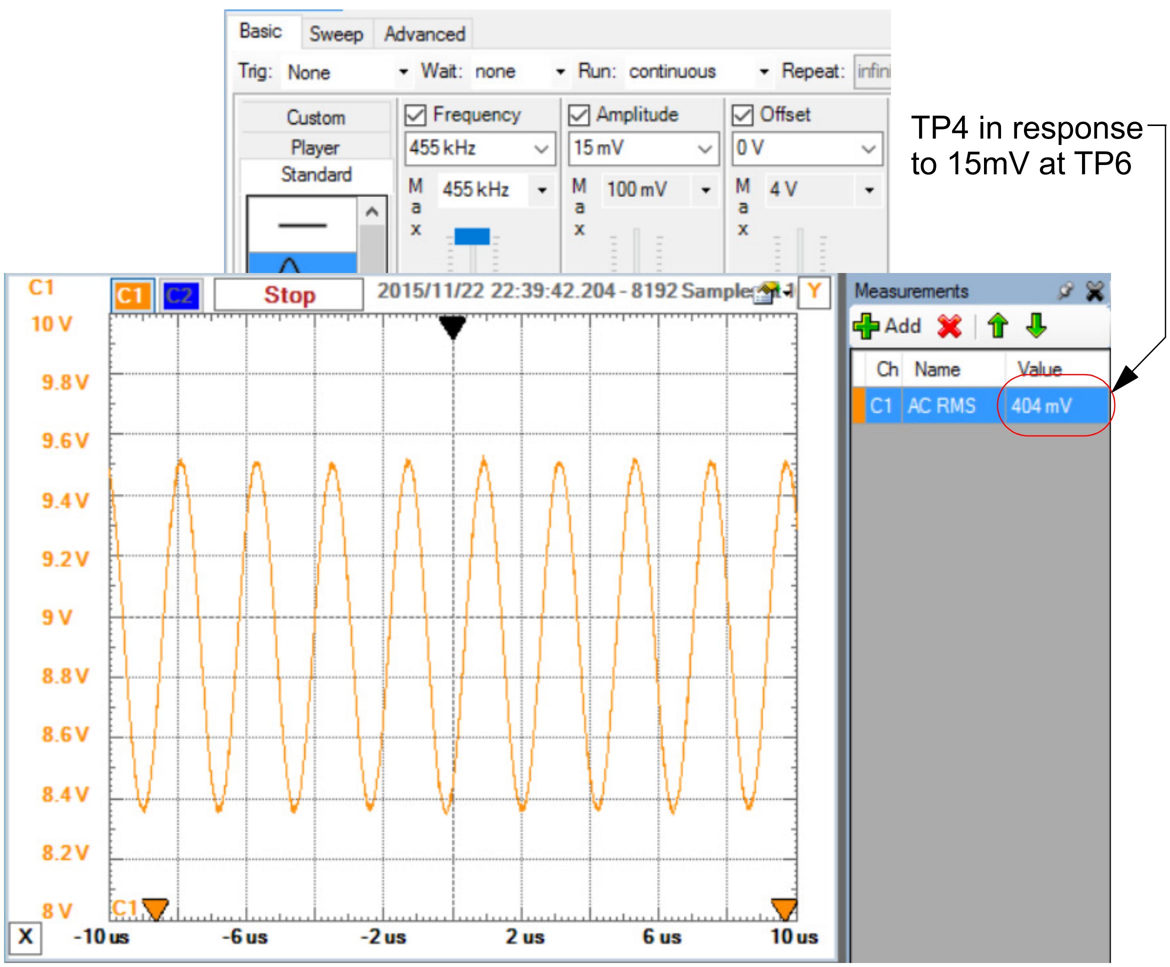
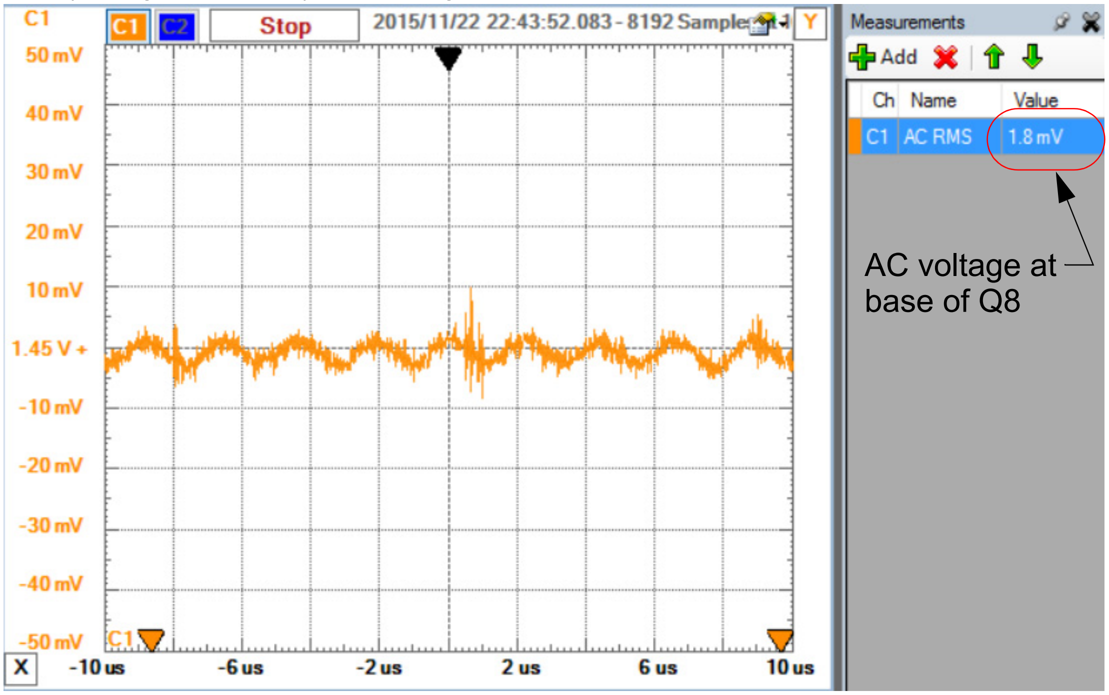


- Verify the gain of Q8 by measuring the AC RMS at the base of Q8:

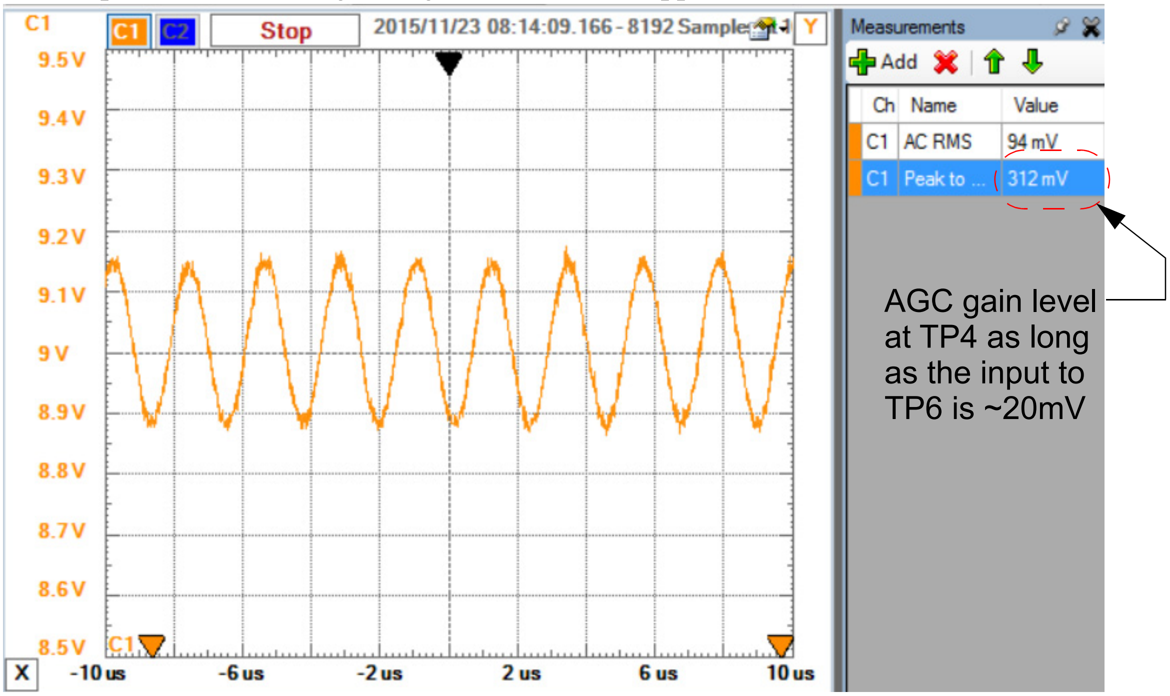


- The voltage gain is

$$A_{v,\,Q8} = \frac{404\text{mV}}{1.8\text{mV}} = 224 \tag{6}$$

- Good as greater than 100 is what is expected (probably optimistic since the measurement at the base is very noisy
- **AGC Action**: Pull the R38 to JP3 jumper so the AGC can function

- The output at TP4 is now gain regulated to 312mVpp



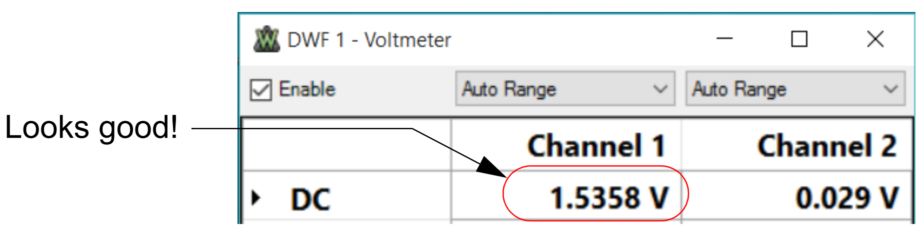
- When the input at TP6 reaches around 20mV the gain leveling action of the AGC begins

Section 5: AM Mixer, AM Oscillator, and AM Antenna

This is the final section in building and testing the AM radio portion of the board. A lot happens in this section.

Static Measurements: Q7 Bias

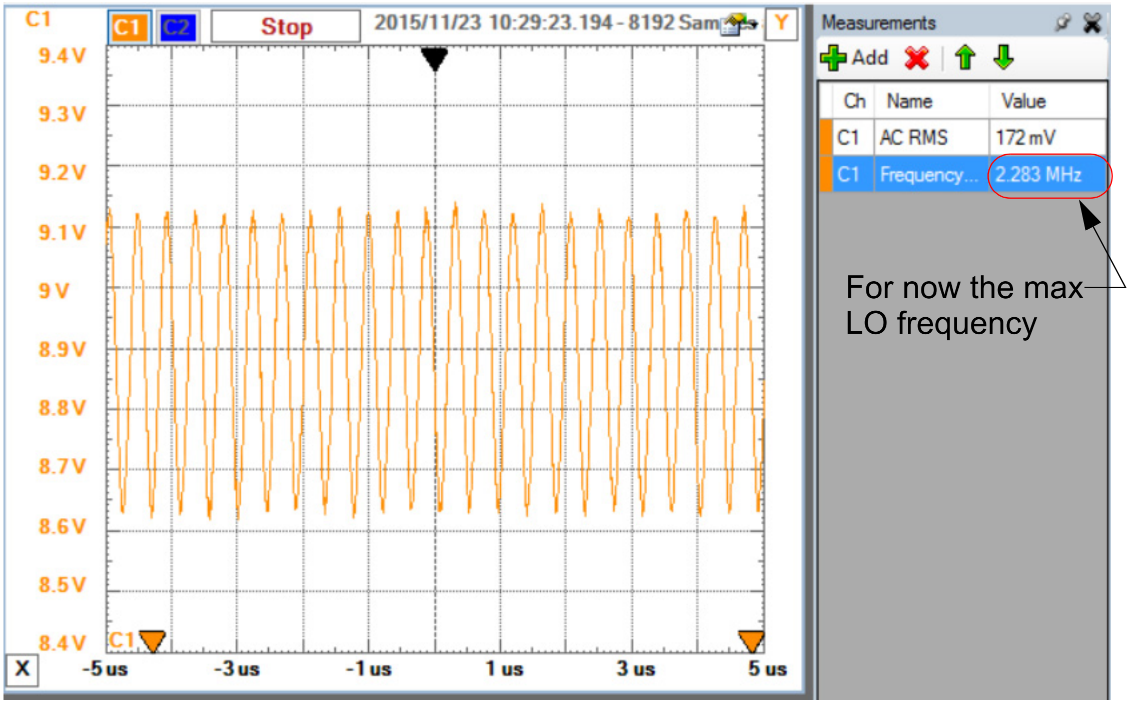
- Check the bias voltage at TP7 which is the base of Q7; should be around 1.6V:

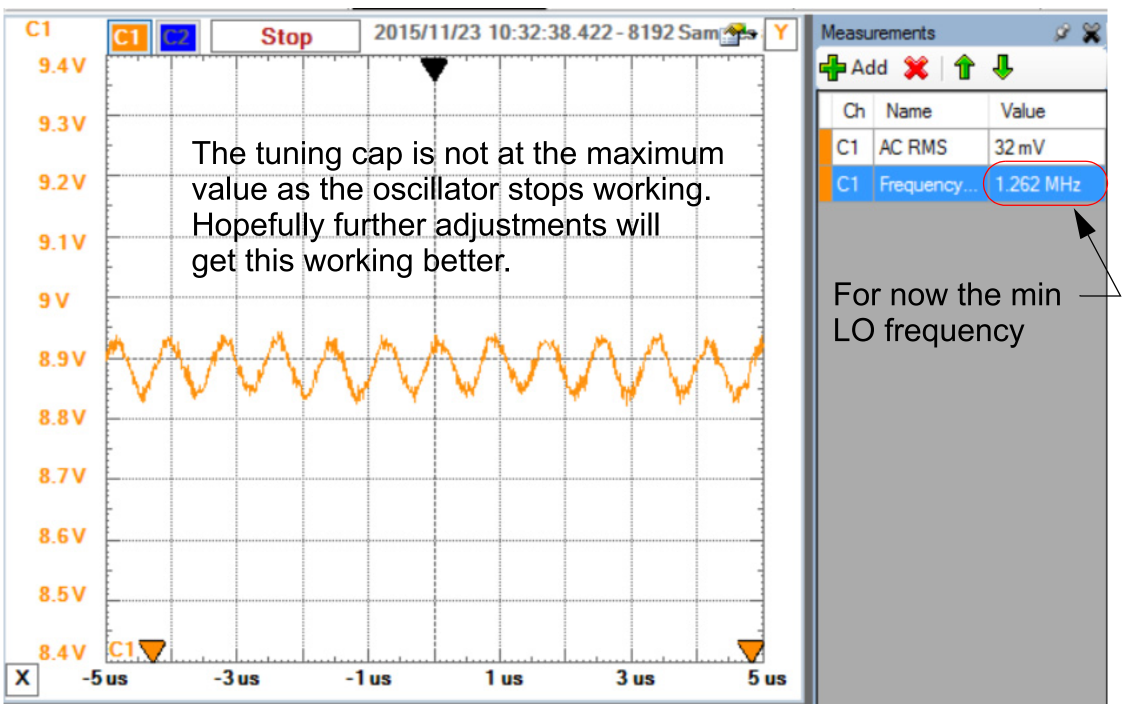


Dynamic Measurements: Observe the Local Oscillator

- Using the scope channel C1 probe at the collector of Q7 and see that the local oscillator signal is present and its frequency changes with tuning cap changes

- Highest to lowest frequency tuning when probing Q7 collector (no adj. to L5 yet)):





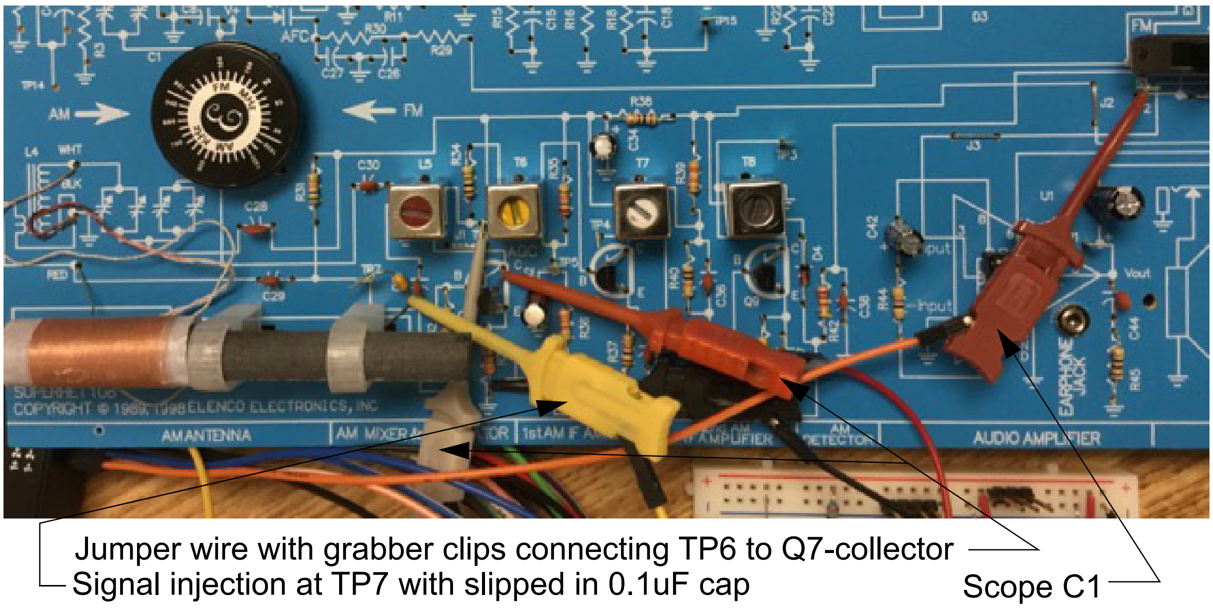
- Note this behavior is similar to the behavior of the breadboard oscillator from Lab 4

Dynamic Measurements: AM Alignment with Test Equipment

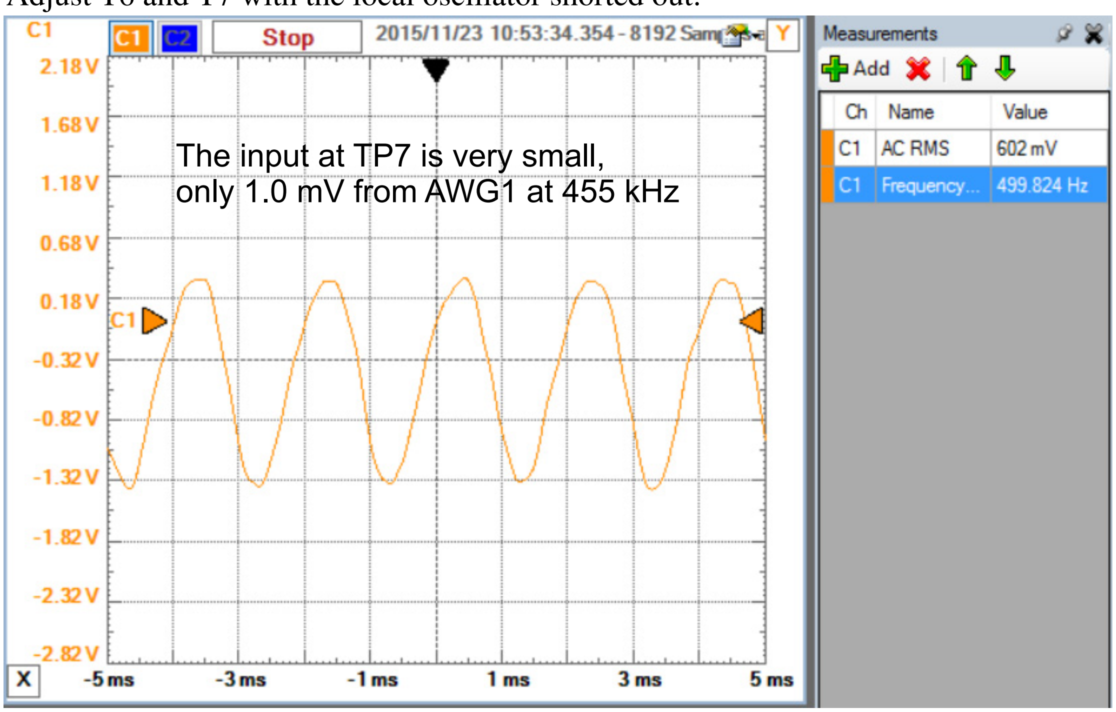
Moving forward into the final set-up of the AM radio

Dynamic Measurements: AC Gain and T7 Transformer Peaking

- The test configuration for this measurement in particular requires a short between two points on the board, that is connect the collector of Q7 to TP6
- Inject a 455 kHz signal at TP7 and observe the output on the scope at TP2
- The test set-up using the Analog Discovery is shown below:



- Adjust T6 and T7 with the local oscillator shorted out:

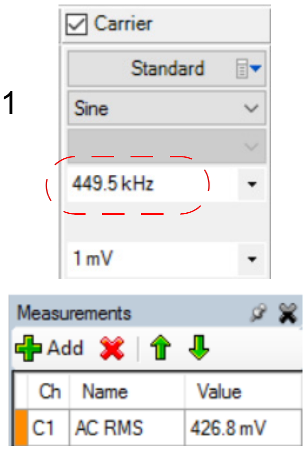


– The process iterative, first adjust T6 and reduce the input level, then adjust T7 and if needed adjust the input level for no distortion, than back to T6, and then T7 one more time

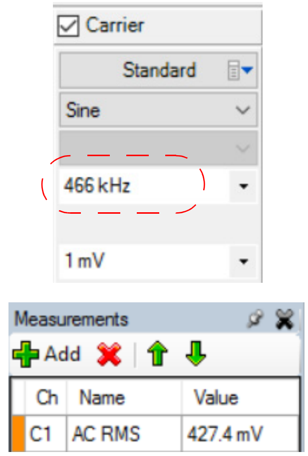
Dynamic Measurement: IF Bandwidth

- Find the 3dB bandwidth using the center frequency AC RMS voltage above, 602mV as the reference, that is tune the input low and then high to see where the amplitude drops to $602 \times 0.707 = 526\text{mV}$:

Tune AWG1 low:



Tune AWG1 high:



- The bandwidth is thus

$$BW_{IF} = 466.0 - 449.5 = 16.5\text{ kHz} \tag{7}$$

  – This value is higher than expected, but certainly greater than 6 kHz

Dynamic Measurements: Oscillator Alignment

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Dynamic Measurements: Antenna Alignment

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