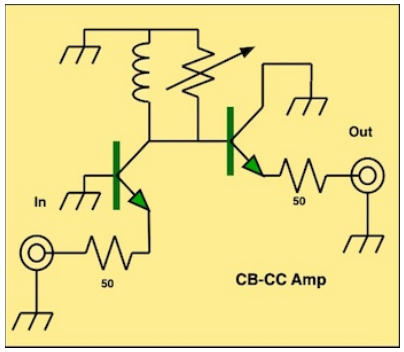

Another Termination Insensitive Amplifier (TIA) Variation

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A popular block diagram for a relatively simple SSB transceiver is based upon bidirectional RF and IF amplifiers.   This design, the BitX, was popularized by the works of Ashhar Farhan, VU2ESE.   The amplifier consisted of a pair of identical circuits configured so the direction of amplification is reversed with a change in bias.

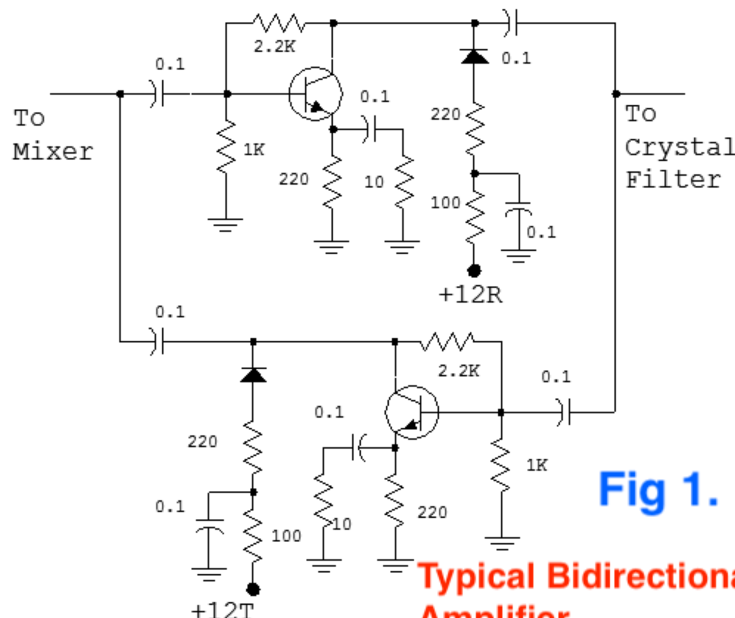

Fig 1.

Typical Bidirectional Amplifier

Farhan's original implementation is shown in Fig 1 where +12R and +12T indicate the function Receive or Transmit, is active. Farhan's amplifiers used two forms of negative feedback, producing a cascadable 50 ohm gain block.

Figure 2 shows a typical application as an IF amplifier. The bidirectional element is between a diode ring mixer and a crystal filter.   Both the mixer and filter are designed to be terminated in 50 ohms.

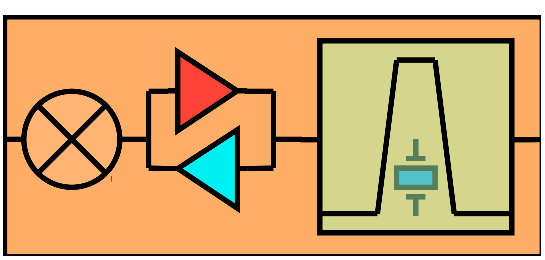

Fig 2.

Presenting 50 ohms to the critical circuits may more difficult than expected.   The carefully designed single transistor feedback amplifier will indeed have a 50 ohm input impedance if the output is terminated in 50 ohms.   But alas, Zin will change if the output load is something other than 50 Ω.   A practical consequence of this change is that the response of the crystal filter during transmit might not be identical to that in receive.[1] One way to fix this problem is to replace the amplifiers with amplifiers that are not sensitive to termination values.   An example of such a circuit is shown below in Fig 3, the creation of Bob Kopeks, K3NHI.[2]   There are other such circuits.

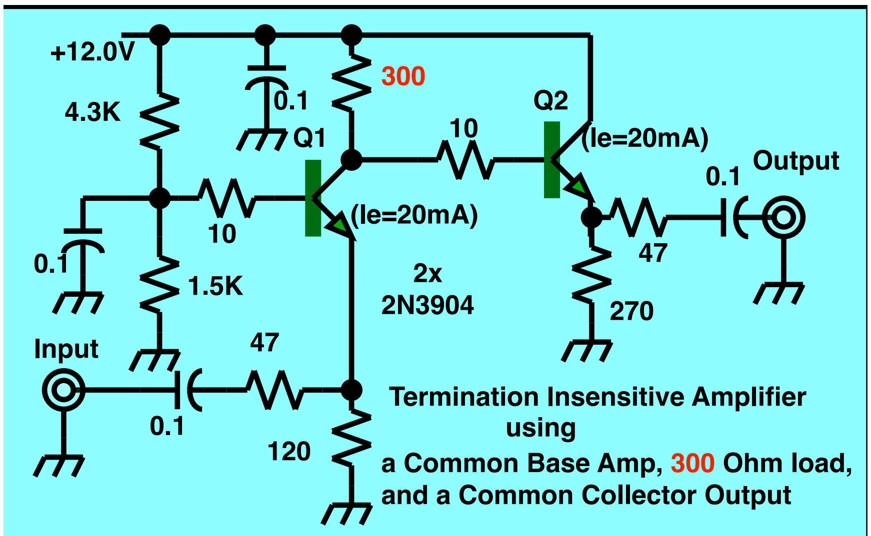

Fig 3. A Termination Insensitive Amplifier (TIA) consisting of a common base amplifier, Q1 and an emitter follower, Q2.   The small signal properties of both blocks are well known.   In this design, Zin is mostly determined by a 47 ohm resistor at the emitter of Q1. The output match is set by the 47 ohms at the Q2 emitter.

This seemingly simple circuit uses a lot of power supply current. Both stages have an emitter current of 20 mA.   High current in Q1 guarantees that overall amplifier Zin will be close to 50 ohms.   The 20 mA in Q2 provides a high output intercept, which limits distortion.

We can evaluate the gain of this circuit without resorting to complicated equations. A common base amplifier (without the 47Ω) will have an input resistance of 27/Ie where Ie is emitter current in mA.   The high current used here, 20 mA, sets the input R at close to 1 ohm.   Adding 47 ohms in series with it provides R close to 50 ohms.   Any signal current applied to the emitter appears with almost no attenuation at the collector.   Assume a voltage at the input coax connector of 1 millivolt.   Ohms law then tells us that signal current is about 1/50, or .02 mA.   That current appears at the collector and flows in the **300** ohm load.   The result is a collector signal voltage of 6 millivolts.

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[1] See https://w7zoi.net/qststuff.html Go to the section titled Small Signal Amplifier Design.

[2] https://w7zoi.net/bidirectional_matched_amplifier.pdf

The second stage, Q2, is an emitter follower. This circuit has a voltage gain of 1, or close. The total load at the Q2 emitter is 100 ohms, which is the 50 (well, 47) ohm series resistor and the 50 ohm load that we apply. The resulting output is 3 mV across the 50 ohm load. Overall voltage gain is then 3, resulting in power gain of 9.5 dB. And that's exactly what we measure.

What if we want a different gain? Clearly, the answer is to change the 300 ohm resistor value. But that would alter the Q1 DC collector voltage which would then alter the DC current in Q2. We need to uncouple the DC and AC properties.

Figure 4 shows our modification. A 72 μH (12 turns #28 on FB-43-2401 Ferrite Bead) inductor fixes the DC voltage of Q1 at nearly 12 volts. A variable resistance then serves as the signal load. The biasing for each stage was altered to preserve 20 mA per device while keeping voltage across each transistor low enough to avoid excess power dissipation.

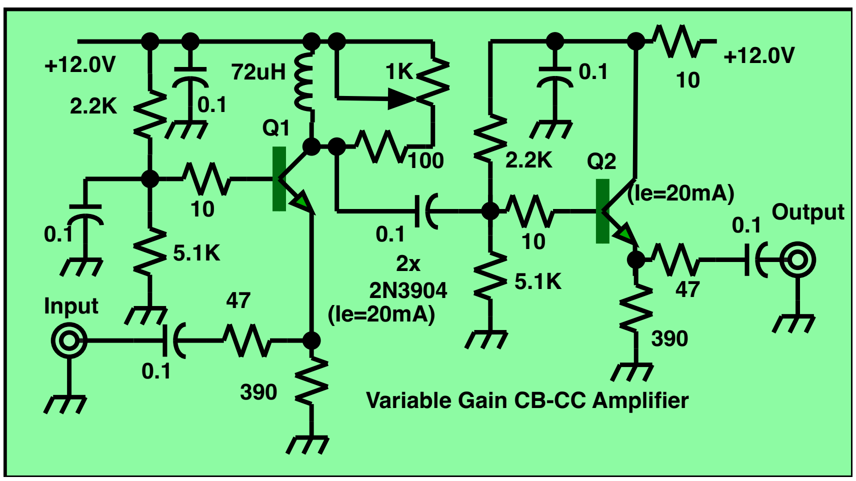

Fig 4. Modified version of the Common Base-Common Collector TIA. The 1K pot provides a gain range of 14.7 dB at a nominal frequency of 10 MHz. Disconnecting the 100 ohm resistor at Q1's collector yields a maximum gain just short of 20 dB.

A signal source was set for an output of +10 dBm and then applied to a step attenuator. This was used to examine the large signal behavior of the amplifier. A plot of the data is shown in Fig 5.

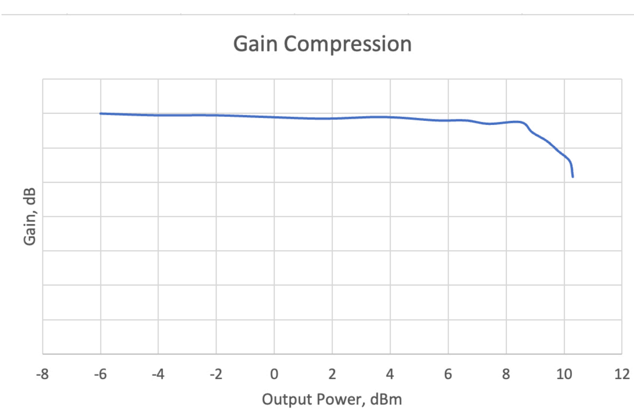

Fig 5. Gain compression occurs as output power is increased. The compression is measurable at relatively low levels, but reaches 1 dB at an output of about +9 dBm.

The test setup used for the compression measurements is shown in the photo of Fig 6. This was taken to illustrate equipment used for measurements, but happened to be taken when the output was close to +10 dBm. The clipping of the output waveform is evident in the 'scope trace. The digital readout of the peak-to-peak voltage was used to calculate output power. This will differ from the power that would be observed in a *proper* RF power meter that actually measures the thermal power delivered to a load.

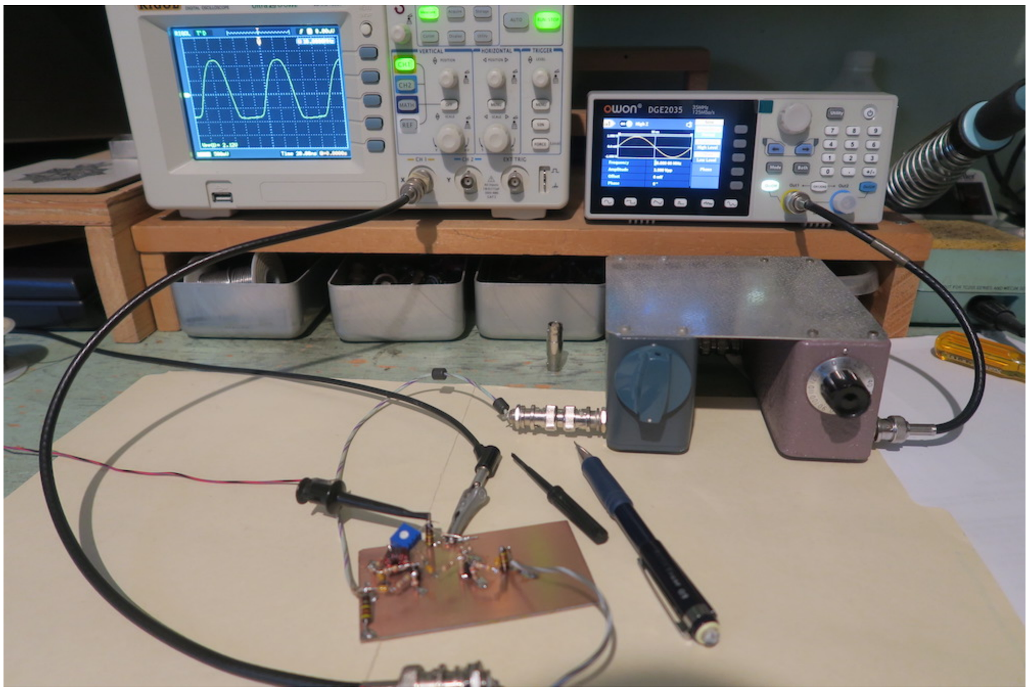

Fig 6. Test bench set up used to measure gain compression. The attenuator is a cascade of HP-355C and HP-355D units. Note the clipping of the output signal shown on the oscilloscope. Although not a feature of the photo, note that a 50 ohm "terminator" is attached to the 'scope front panel and serves to terminate the coax coming from the circuit being tested. The 'scope operates at X1 vertical gain for these measurements.

The 100 ohm resistor at the collector of Q1 was opened (see Fig 4) resulting in a higher gain of 19.4 dB. The signal source was then varied from 1 to 30 MHz producing the data in Fig 7 below.

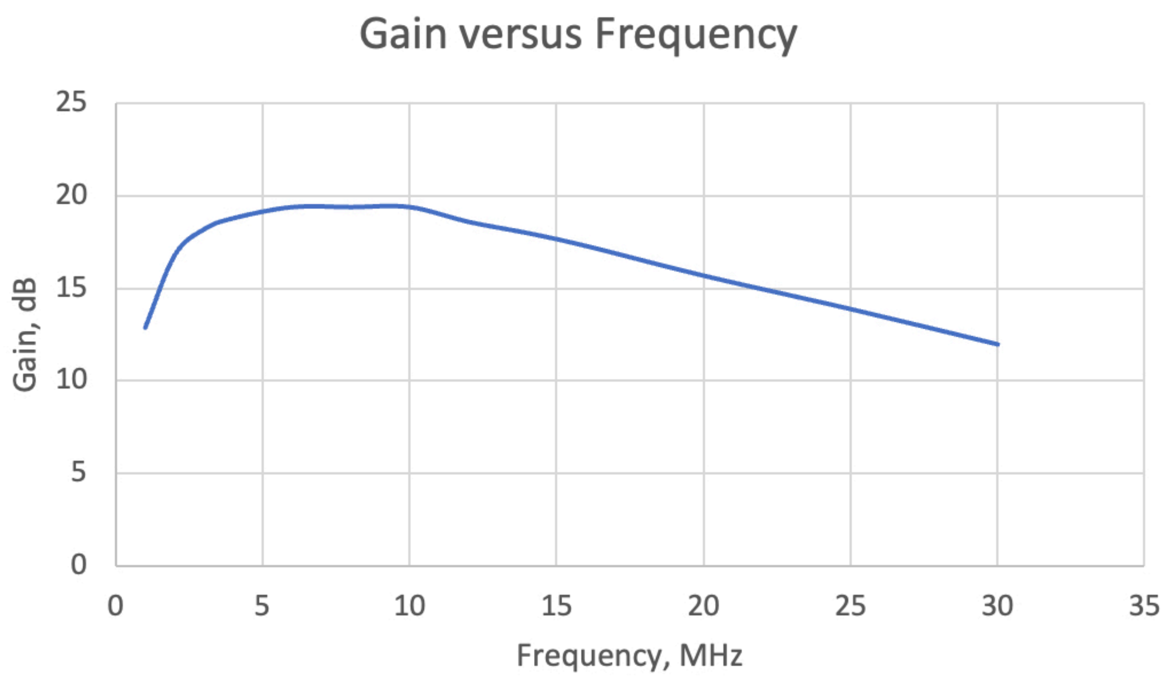

Fig 7. Gain versus frequency for the amplifier of Fig 4. The gain determining load is a parallel combination of the bias networks and loss in the ferrite bead. If more low frequency gain is needed, increase the number of turns.

Figure 8 below shows the breadboarded amplifier. This is classic "*ugly construction*."

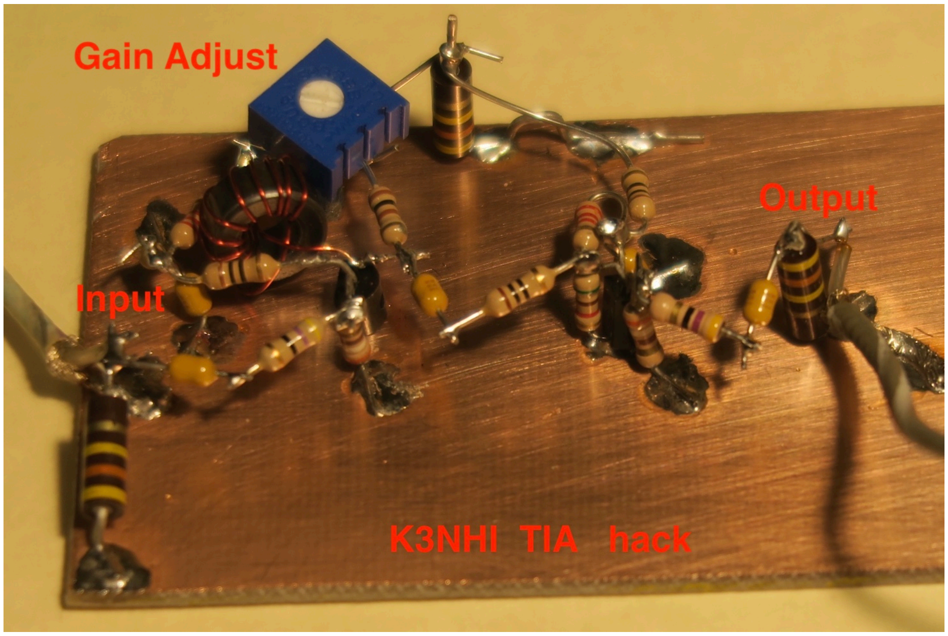

Fig 8. The amplifier that was measured in this note. The three half-watt 430K ohm resistors serve as mechanical supports and have nothing to do with the circuit operation.

Additional Thoughts

The amplifier tested here was just one side of a bidirectional pair. The requirements will be different for each direction. But if the amplifiers are truly termination insensitive and set up for 50 ohms, filter response should be identical in each direction. It is usually important to have both ends of a filter terminated in a well defined load.

We measured gain compression here, for it's an easy thing to measure that is also easy to understand. A more useful parameter for an amplifier, especially when designing a SSB radio, is amplifier intercept. It's not used as much by radio amateurs, for it's rather mathematical in it's definition. It's is also a bit more difficult to measure, requiring a spectrum analyzer or similar measurement receiver. Bipolar amplifiers where the output is extracted from the collector typically show an output intercept that is around 13 dB higher than the output 1 dB compression power. But this is just a rule of thumb and should never be used to replace an actual measurement. Be sure to specify input or output intercept.

The reader may well ask why intercept is a big deal. It relates to intermodulation distortion. Builders in the early days of SSB related all distortion as being created in the output stage of a transmitter. We know better today. All of the stages in a cascade contribute something to intermodulation distortion. If all stages are individually characterized for gain and intercept, the behavior of the cascade can be calculated and even optimized.[3]

[3] Hayward, Campbell & Larkin, "Experimental Methods in RF Design,"ARRL 2003. See Chapter 6. The program "Cascade" treats cascaded stages, calculating noise figure and intercept for a cascade of up to 10 stages.