2023 FDIM - 2 TRANSISTOR RECEIVER CHALLENGE
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40m - Two Transistor Dual Reflex Regenerative Receiver

The concept of reflex receivers is not new, although some may not have heard of them. In the simplest terms, a reflex receiver makes use of a single device to do both RF and audio amplification. This application makes use of two transistors to do that. In addition, one also makes use of regeneration to increase gain and selectivity.

I first observed the use of reflex technology in one of the first transistor receivers I purchased as a kid. In the 1960's the Japanese had manufactured a two transistor radio that used a reflex circuit to keep the parts count down. It wasn't very sensitive or selective for obvious reasons using a TRF front end. However, it did receive local stations. They sold the radios as toys, thus avoiding tariffs in place at that time.

Like most kids of my era, my fascination with regenerative receivers began with Alfred Morgan's "The Boy Electrician". Constructed on a pine board, a 1H4 "mhotron" operated as a grid leak detector with a plate circuit tickler winding, this simple "regen" opened up the world of radio for me. Using a long wire antenna, and winding coils for both AM and SW bands, I heard stations around the world. Regens are surprising simple and versatile, in that these receivers can detect AM, CW, SSB, and even FM. Both novel and simple, they require patience when tuning and become more impractical as you approach VHF.

This was my second year attending FDIM, and when David announced that the challenge would be a 40m two transistor receiver, I thought it might be fun to enter. My background hardly qualifies me as any type of RF designer, and certainly the prospect of winning this event never crossed my mind. I just thought that a REFLEX REGEN would be a fun addition to the mix. This receiver is an early attempt, and there is lots of room to improve this circuit.

Like most procrastinators, I never really gave it a thought till about six months before this year's event, and only diddled with some ideas after that. I committed myself to enter about March, and drew up some circuits. The original design was configured as a reflex regenerative detector with an audio amplifier. It wasn't long after that when I decided to include a second reflex circuit, combining the audio output stage and RF amp. That seemed natural since the collector current is chosen to be much higher here. Almost nightly for about a month, referring to "Experimental Methods", "Radio Frequency Design", and the Amidon Coil Forms book, several coils and transformers were wound, tests made, and experiments with a variety of combinations were made until I arrived at (what I considered) a usable prototype.

It's funny how circuits evolve. I found that with little modification, the original design could be adapted to support a reflex design. Perhaps the revival of the reflex circuit in this example will inspire some who will find this application intriguing. Some novel ideas have been applied in this little receiver and are worth a look. The receiver tested at FDIM with its high gain and lack of shielding made this radio nearly impossible to use. However subsequent variations of this design have shown promise. We have verified AM detection to -105dBm in a later circuit, although CW was another matter.

CIRCUIT OVERVIEW
Tuning range 40m 6.8 - 7.4 MHz
Two Transistors in reflex mode: common base for RF, and common emitter for audio.
Both transistors chosen for this application were 2N3904 NPN devices.
Operation from $12V_{DC}$
Current consumption less than 20mA
Input impedance nominally 50Ω
Output impedance 600Ω (telephone transformer)

Refer to the schematic for all references in the following descriptions.

DC CIRCUIT DESCRIPTION

The base bias of Q1 is determined by resistor divider R3 and R4. This sets the emitter voltage near 4.5V such that an emitter current around 15mA is established with R1 and R2. The higher current was chosen so that the RF and audio output circuits would not be easily overloaded. Note that the base of Q1 is directly coupled to the collector of Q2 via RFC L1 (more about that later). With the 600Ω audio transformer connected to the collector of Q1, its DC voltage sits near the supply voltage.

The second stage is biased near cutoff. Diode D3 is used to offset Q2 base emitter voltage so that only a small DC voltage near 0.25V appears across the two germanium diodes D1 and D2. This keeps them very slightly reversed biased. The same voltage appears across R5, the 2.7kΩ emitter resistor. This sets the DC emitter current near 80uA. The low current was chosen for this transistor in order to improve control of regeneration. Actual measurements did fall within 20% of these predicted values, but R6 had to be selected by hand.

Originally the collector circuit of Q2 had a resistive load and was capacitively coupled back to the base of Q1, but since the base voltage was about 6V, direct coupling was chosen which reduced the parts count without significantly affecting performance. The challenge called for detecting the smallest signal, so overloading was not a concern here.

RF SIGNAL CIRCUIT DESCRIPTION AND PATH

The first stage consists of Q1 configured as a common base low gain RF amplifier. Capacitors C4-C6 serve as bypass capacitors. Toroid T1 was wound assuming a 50Ω input, and the secondary tuned circuit was wound to cover 6.8MHz to 7.5Mhz with an unloaded Q of about 10. A low impedance tap on the secondary was chosen in an effort to match the 2.5Ω emitter input impedance without significantly loading the tuned circuit. The RF signal at the collector of Q1 is coupled via toroid T2 into Q2. It sees a high input impedance of about 50Ω and a tuned secondary that is wound identically as T1. The main tuning capacitor is a ganged device, and each section was trimmed to cover the 40m pass band. Gain of the first stage was measured to be about 10x, and in the original circuit needed shielding.

The second stage consists of Q2 acting as another common base RF amplifier, however it is biased near cutoff. Experimentation of values for R6 and C11 were needed to get enough gain to allow the stage to oscillate (regenerate) across the band. Positive feedback to the secondary of T2 is accomplished with the MV2109 varactor D4 in series with C11. Regeneration is controlled via R8 and adjusted with R9, a 10kΩ potentiometer. As expected, it does shift the tuning when adjusted.

AUDIO DETECTION AND AMPLIFICATION

The RF signal present at the collector of Q2 is coupled to the germanium diode detector via C12. This detector is somewhat novel, using two germanium diodes D1 and D2 acting as a charge pump that develops the audio signal across R7, the 10kΩ resistor. The RF component of the audio signal is removed by C10, the bypass capacitor at the base of Q2. Thus the resulting audio signal appears across R7, and is fed into the base of Q2 which now functions as a common emitter audio amplifier. The emitter of Q2 is bypassed to increase the audio gain (not much here) and the collector current carries the audio signal through L1 the RFC and back into the base of Q1.

We again make use of the reflex circuit by feeding the audio signal into the base circuit of Q1, here it is acting as a common emitter audio driver circuit. Any RF appearing at the base of Q1 is also bypassed with C2. With an emitter current near 15mA, and a 47Ω unbypassed emitter resistor, this audio stage gain should approach 12 with T3, the 600Ω audio transformer. With the receiver configured for operation at $12V_{DC}$, an audio signal output can swing over $4V_{pp}$, making about 3.3mW into a 600 load connected to transformer T3.

Only 35 components were used to create this receiver, including two hand wound T50-6 toroid transformers. It functions as a four transistor receiver, and gets a little help with regeneration to improve selectivity and gain. The radio entered in the competition was hand wired and mechanically stable, but did not have enough shielding between stages, so was difficult to control, as David noted.

I would welcome your comments regarding this reflex regenerative receiver, as well as ideas for improvement. The coil and transformer matching still eludes me somewhat, there is certainly room for improvement here. I encourage those with experience building regens to build this detector and check it out. The radio shown at FDIM, although it worked, suffered from trying to do too much in a small space without proper shielding.

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