Lecture 26: Receiver Incremental Tuning. Crystal Oscillators

The NorCal 40A includes a receiver incremental tuning (RIT) circuit to offset your receiver frequency from your transmitter frequency.

Why include this feature? Because other transceivers may be operating with receivers and transmitters that aren't perfectly aligned (in frequency). Or, perhaps their *transmitter* has drifted in frequency due to heating while their *receiver* has not.

With an RIT, you can finely adjust your receiver frequency without affecting the transmitter frequency. To operate the RIT:

1. Adjust your VFO so your transmitted signal is being received by the other station.
2. Next, adjust your RIT so your receiver matches his transmitter frequency. Cool!

Using the RIT helps avoid a "dog-chasing-his-tail occurrence" in which station 2 adjusts his transceiver to receive 1 properly but also changes his transmit frequency. Then station 1 adjusts his transceiver for reception, but changes his transmit frequency, and so on.

In Prob. 26, the VFO tune pot (R17) is connected to ground through R15 as shown in Fig. 11.15:

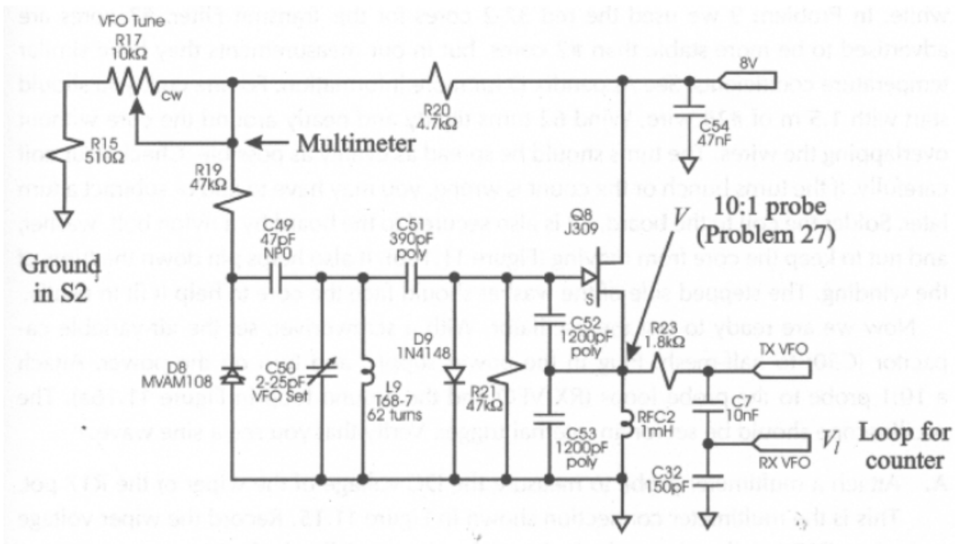


Figure 11.15. The VFO in the NorCal 40A.

Later towards the end of Prob. 27, R15 is removed from ground and connected to pin 7 of U6, which is the LM393N dual comparator, as shown in Fig. 11.20. This forms the RIT:

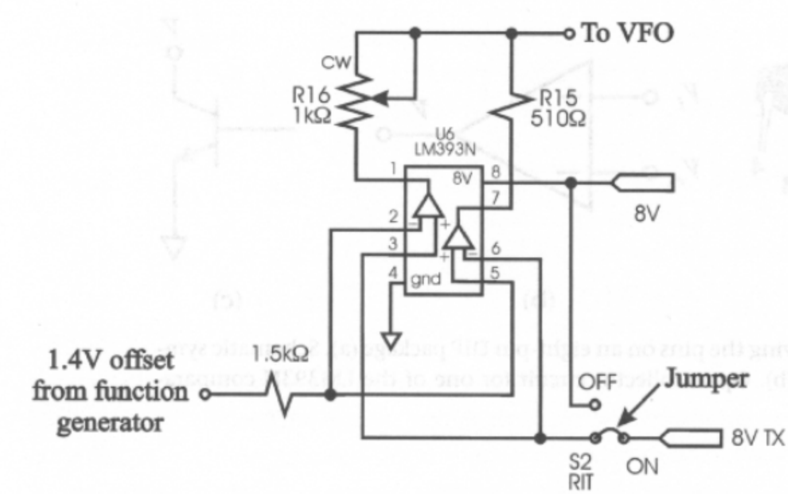


Figure 11.20. The RIT circuit. The original NorCal 40A circuit has a switch S2 to turn the RIT on and off. In our measurements we will not use the switch, but we will add a jumper so that the RIT is always on.

How does this RIT work? It's actually very simple. The comparator is similar to an op amp except with an "open-collector" output as shown in Fig. 11.18:

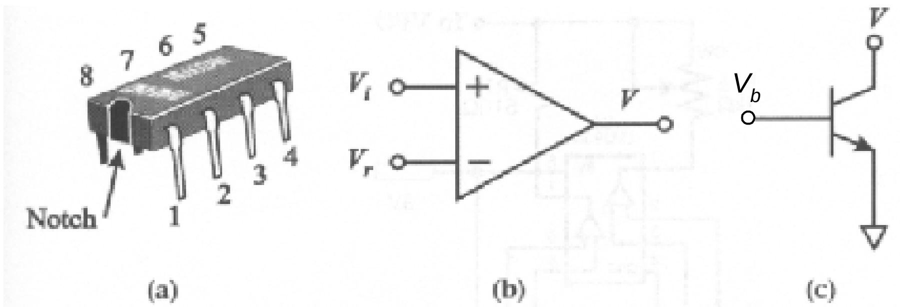


Figure 11.18. Identifying the pins on an eight-pin DIP package (a). Schematic symbol for a comparator (b). Open-collector circuit for one of the LM393N comparators (c).

Referring to Fig. 11.18(c), the output pin of the comparator is a BJT collector terminal. This pin is either open- or short-circuited to ground depending on V_i and V_r, as:

- $V_i > V_r$, then V_b is low and V is open circuited ("off"), or
- $V_i < V_r$, then V_b is high and V is short circuited ("on").

There are two situations important to us in the NorCal 40A. In both, we'll assume that the RIT (S2) is "on":

1. With "8V TX" **high**, then the left comparator in Fig. 11.20 is "off" (low) and the right comparator is "on." This means that the VFO is connected through R15 to ground, and R16 is effectively open circuited. This is the standard transmit configuration studied in Prob. 26.

2. With "8V TX" **low**, then the left comparator is "on" and the right comparator is "off." Therefore, the VFO is connected through R16 to ground and R15 is effectively open circuited.

Now, by changing R16 we can vary the bias voltage of the varactor D8 and hence the receive frequency (remember that "8V TX" is low when receiving) and *only* affect the receiver frequency. This is called receiver incremental tuning.

Crystal Oscillators

Besides the VFO, there are two other oscillators in the NorCal 40A. These are the Beat Frequency Oscillator (BFO) and the Transmit Oscillator (TO).

Both are crystal oscillators. These use a BJT inside the SA602AN IC as the amplifier plus an external quartz crystal and a voltage divider network to make the feedback network. Together, these form a crystal oscillator, as shown in Fig. 11.10:

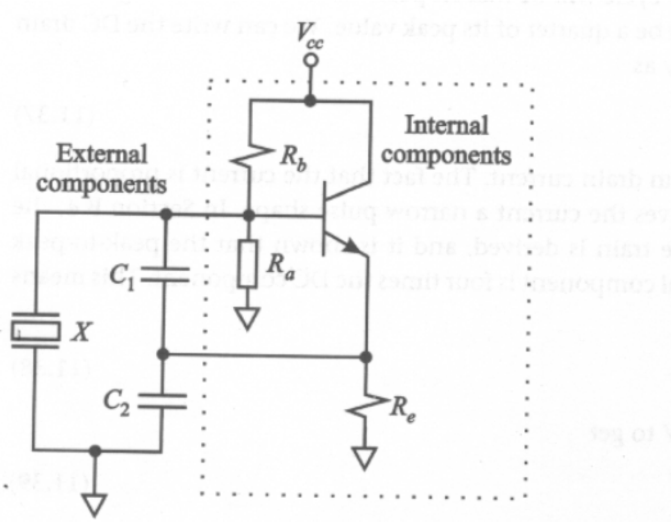
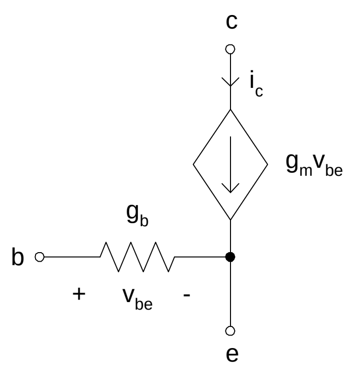


Figure 11.10. Clapp crystal oscillator in the SA602AN integrated circuit that is used for the Transmit Oscillator and the Beat Frequency Oscillator.

We can recognize the Clapp oscillator topology in this figure by the capacitive divider/feedback network. This oscillator is very similar to the JFET Clapp oscillator used in the VFO.

The small signal model for this oscillator is shown in Fig. 11.11. Here, we are using a transconductance model for the BJT:



$$g_b = \frac{1}{r_\pi} = \frac{g_m}{\beta}$$

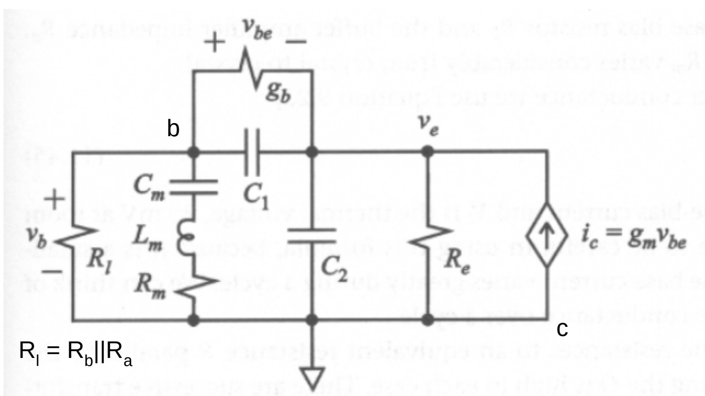
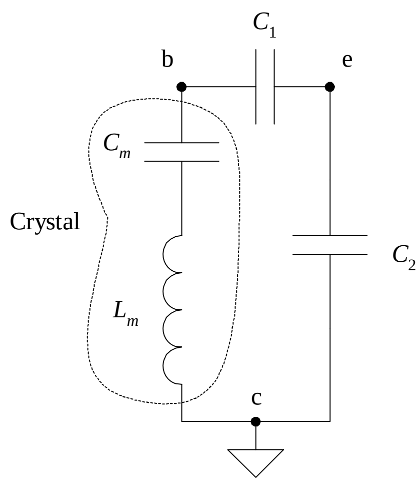


Figure 11.11. Equivalent circuit for the Clapp crystal oscillators.

To determine the approximate resonant frequency, we note that the source-free, lossless circuit that the inductor "sees" is



Therefore,
$$f_0 = \frac{1}{2\pi\sqrt{L_m C}} \text{ [Hz]} \tag{11.43}$$

where
$$C = \left[\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_m}\right]^{-1} \text{ [F]} \tag{11.44}$$

The startup condition for this oscillator is derived in the text to be:

$$g_m > \frac{(C_1 + C_2)^2}{C_1 C_2 R_l} + (\omega_0 C_1)(\omega_0 C_2) R_m + \frac{C_2}{C_1}\frac{I_b}{V_t} + \frac{C_1}{C_2 R_e} \text{ [S]} \tag{11.47}$$

In this expression, I_b is the base bias current and V_t is the thermal voltage ($\approx$ 25 mV at room temperature).

The startup condition in (11.47) is a rather complicated expression largely because of the many sources of loss in the circuit.

Lastly, the peak-to-peak output voltage (across the load R_l in Fig. 11.11) is derived in the text as

$$V_{pp} = \frac{4I_o R_l C_1}{C_1 + C_2} \text{ [V] (if } R_l \text{ is dominant loss)} \qquad (11.50)$$

where $R_l = R_b \parallel R_a$ and I_o is the dc component of the emitter current.

We see in this expression that with $C_2 \gg C_1$, then $\boxed{V_{pp} \propto C_1}$. This effect will be quite noticeable as you adjust:

1. C17 in the BFO (C17 is "C_1" for the BFO),
2. C34 in the Transmit Oscillator (C34 is "C_1" for the TO).

The Transmit Oscillator has an additional series inductor L5 that is used to shift the oscillator frequency to a value different from the BFO. What purpose does this serve in the radio?