100-1007 No Tempco VCO

1. Theory Of Operation.

The VCO uses a purely electronic means of compensating for the scale drift in exponential transistor pair. This is not a new concept. The Curtis CEM3340 VCO did this some twenty years ago. But, that part is no longer being made. So, coming up with a way to do this was not an easy thing to do. In fact, I have been trying to do it ever since the CEM3340 first came out simply because it was a puzzle to solve. It wasn't until 1998, however, that I really started working on this problem in earnest. And, there were a few false starts, but it would seem I now have a circuit that does this job fairly nicely. While this does a considerable complexity to the circuit, it does not cost a whole lot, compared to the solution using a temperature compensating resistor. Those resistors can cost between $5 to $10 each. There are less expensive parts, however, they don't have the exact temperature dependence needed. There are ways to get around all this, but some of the solutions are not very satisfactory.

Looking at the schematic, U9A and U9B make up the gain control element that controls the temperature coefficient of the voltage applied to the base of Q6A (pin 2). The LM13700 connect in this fashion does two things. First the Tempco of U9A is canceled out by the Tempco of U9B, and second, the non linearity's of the two amplifiers also cancel each other out. The overall linearity is about 0.1%.

The transfer function for this combination is:

$$\mathbf{V_O = R_{47} * g_{mU9B} * V_{IN} / (g_{mU9A} * R_{44} + 1)} \qquad \mathbf{(1)}$$

G_{mU9A} will nominally be 0.0081 mhos.

The current that controls G_{mU9B} is a bit more problematic. Q6C and the reference leg of Q6A (Pins 3,4,5) form a band gap reference. The output voltage will be proportional to absolute temperature. For room temp it should be:

$$\mathbf{V_{BG} = V_T * \ln(500);\ V_T = 0.026V\ @\ room\ temp} \qquad \mathbf{(2)}$$

The 500 value is the ration of the two currents, which is set by the ration of R43/R101 = 500. The amplifier supplying the current has a gain of 10. So, IABC2 will be:

$$\mathbf{I_{ABC2} = 10 * V_{BG} / R_{57} = 10 * 0.1616 / 4.02K} \qquad \mathbf{(3)}$$

So I_{ABC2} will be about 0.4 mA.

This will make GMU9B nominally 0.0077 mhos. So, substituting all of this into the above equation (1) we get:

$$V_O = 0.01905 * V_{IN} \quad (4)$$

So, as you can see, we will get about 19mV/V at the base of Q6A (Pin 2), which is a bit high perhaps, but that is what the pot is for.

IABC2 will vary with temperature, because, that is what it is supposed to do, always adjusting the gain of the VCA so that the scale factor will remain constant with temperature.

Q6B is used to generate a current that can be used to correct for the bulk resistance of the exponential transistors. The collector of Q6B is fed into an opamp that converts the current to voltage. R39 then allows you to adjust the amount of voltage that gets fed back into the converter. This seems to be a very clean way of generating this signal. We don't need to worry about offsets added by the usual method of using the output of the reference leg servo amp.

The oscillator itself is just a standard sawtooth oscillator that has been around for a long time. You will find this oscillator in past issues of Electronotes. The circuit is one that was done by Terry Michaels. It is also sometimes referred to as the ASM-1 oscillator. The sawtooth output of the oscillator then goes into wave shapers that are pretty much standard. I did add a divider that will produce divide by 2,3, and 4 ratios.

II. Construction

You should note the following changes.

For the REV N.C. board, the silkscreen reads wrong for the following parts.

Reference Designator	Silkscreen Reads	The value should be
R47	200	1K
R57	11.3K	4.02K
R58	10K	11.3K

The only part you may have difficulty finding is the CA3280. All of the other parts should be commonly available. Most can be purchased from either Digikey or Mouser.