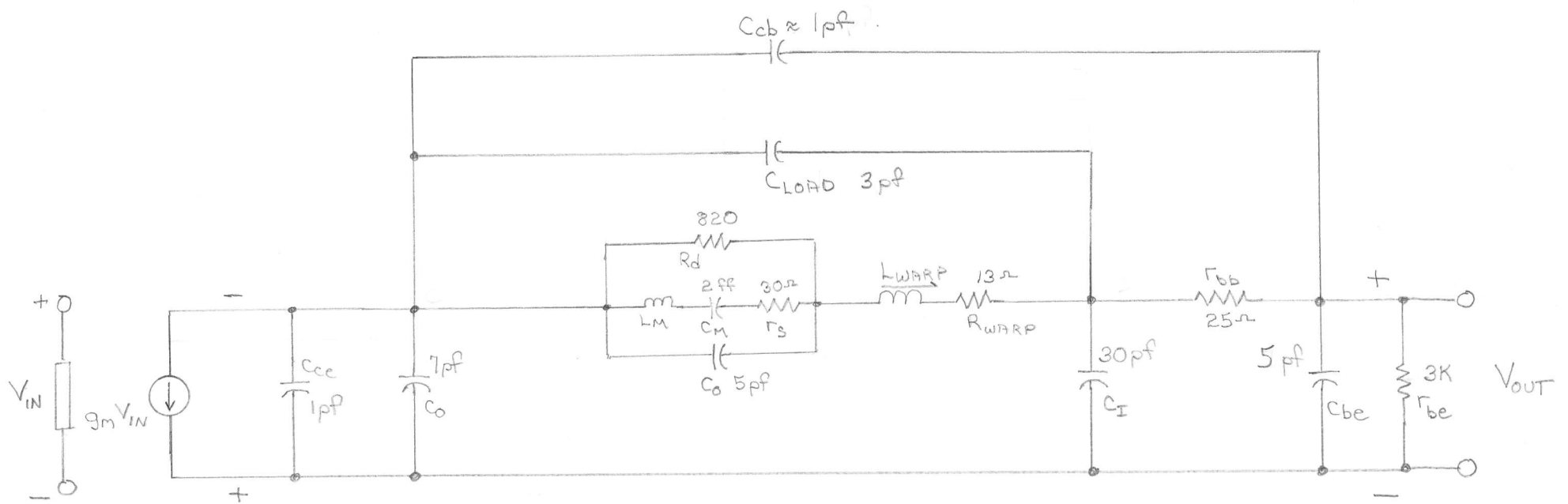


Loop Gain Model



$$g_m \approx .03$$

$$C_{be} \approx \frac{g_m}{2\pi f_c}$$

For Oscillation

V_{OUT} must be $> V_{IN}$
with \angle of 0°

$$g_m \approx \frac{|I_c|}{V_T} \approx \frac{|I_c|}{T/11,600}$$

$$@ 25^\circ C \approx \frac{|I_c|}{.026}$$

$$\approx \frac{.75 \text{ mA}}{.026}$$

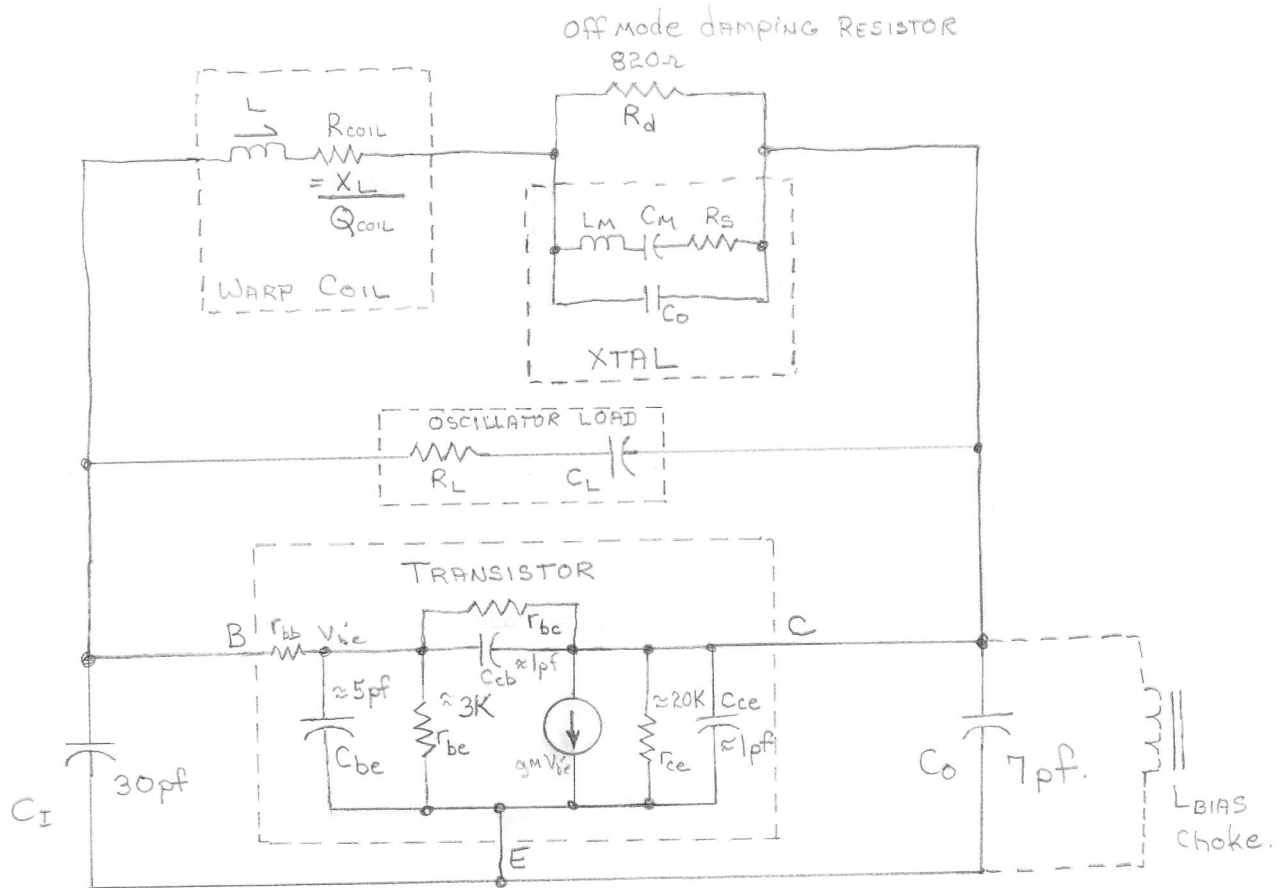
$$\approx .029 \text{ mhos}$$

$$\text{or } 29 \text{ mmhos}$$

3rd OVERTONE OSCILLATOR Model

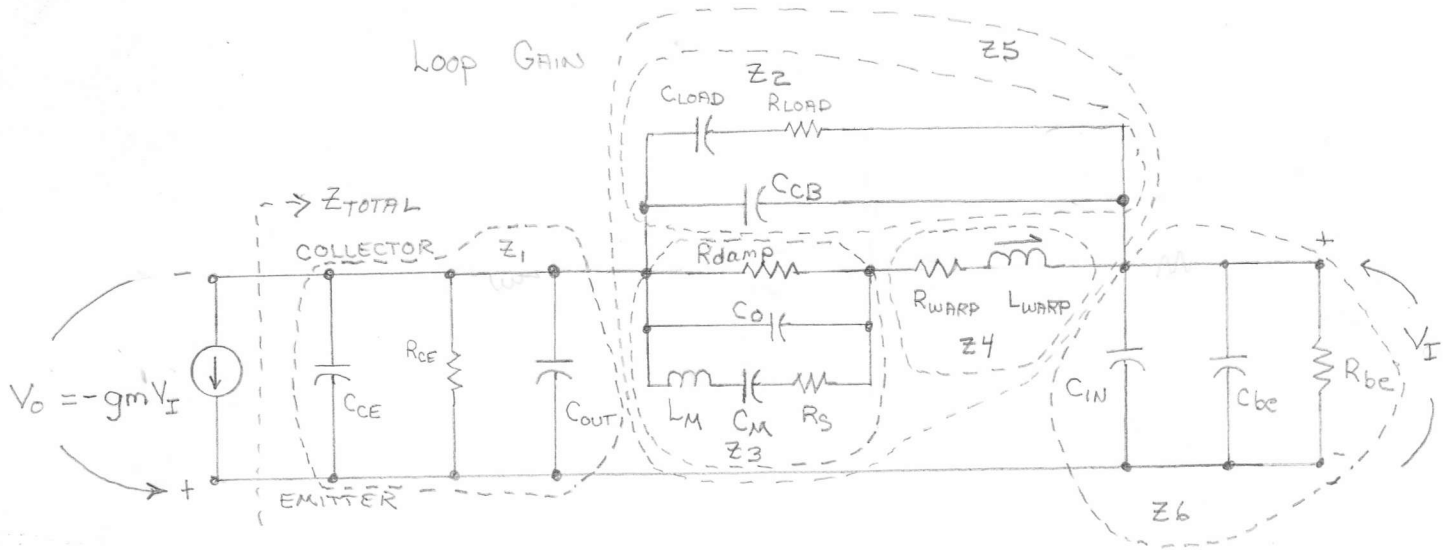
R. CRAIG 11/21/84

BASIC OSCILLATOR



Any node of circuit can be selected as reference or ground point. ACTUAL selection point should be determined by ease of d.c. biasing and method of power output pick off. Most pagers use the collector of the transistor as A.C. ground reference. For ease of analysis for loop gain we can use the emitter of the transistor as the model's ground reference.

LOOP GAIN



MUST
GIVE

HP41C
REG. LIST

- * R0 - R_{be}
- * R1 - C_{be}
- * R2 - C_{cb}
- * R3 - C_{ce}
- * R4 - C_{in}
- * R5 - C_{out}
- * R6 - R_{load}
- * R7 - C_{load}
- * R8 - L_{warp}
- * R9 - C_m
- * R10 - R_s
- * R11 - XTAL f₃ IN HZ
- * R12 - XTAL C₀
- * R13 - C_{total}
- * R14 - F_{warp} IN PPM
- * R15 - XTAL L_m
- * R16 - F_{osc} IN HZ
- * R17 - TEMP
- * R18 - TEMP
- * R19 - |Z₁|
- * R20 - XZ₁
- * R21 - |Z₂|
- * R22 - XZ₂
- * R23 - |Z₃|
- * R24 - XZ₃
- * R25 - |Z₄|
- * R26 - XZ₄
- * R27 - |Z₅|
- * R28 - XZ₅
- * R29 - |Z₆|
- * R30 - XZ₆
- * R31 - |Z_{total}|
- * R32 - XZ_{total}
- * R33 - |LOOP GAIN|
- * R34 - XLOOP GAIN
- * R35 - transistor |G_m|
- * R36 - XG_m
- * R37 - R_{ce}
- * R38 - R_{damp}
- * R39 - R_{warp}

$$Z_1 = \frac{1}{\frac{1}{R_{ce}} + j\omega_0(C_{ce} + C_{out})}$$

$$Z_2 = \frac{1}{\frac{1}{R_{load} - j\frac{1}{\omega_0 C_{load}}} + j\omega_0 C_{cb}}$$

$$Z_3 = \frac{1}{\frac{1}{R_{damp}} + j\omega_0 C_o + \left(\frac{1}{R_s + j(\omega_0 L_m - \frac{1}{\omega_0 C_m})} \right)}$$

$$Z_4 = R_{warp} + j\omega_0 L_{warp}$$

$$Z_5 = \frac{1}{\frac{1}{Z_2} + \frac{1}{Z_3 + Z_4}}$$

$$Z_6 = \frac{1}{\frac{1}{R_{be}} + j\omega_0(C_{in} + C_{be})}$$

$$V_o = -g_m V_I \cdot Z_{TOTAL}$$

$$\frac{V_I}{V_o} = \frac{Z_6}{Z_5 + Z_6} \quad Z_{TOTAL} = \frac{1}{\frac{1}{Z_1} + \frac{1}{Z_5 + Z_6}}$$

$$\text{Loop gain} = -g_m Z_{TOTAL} \cdot \frac{Z_6}{Z_5 + Z_6}$$

TRANSISTOR PARAMETER MEASUREMENT

Developing a model for the transistor that is best suited for loop gain evaluation from measured transistor parameter is a unique problem within itself.

Scattering or "S" parameter has evolved as the easiest method of transistor parameter measurement. This method is a measurement of the four, two part parameters, S_{11} , S_{12} , S_{21} , S_{22} of the transistor with a standardized source and load impedance. The standardized source and load impedance is typically selected to be 50Ω . This impedance has been selected because of the standardized array of test equipment at this impedance and the unlikeliness that a device will be unstable at such a low termination impedance. As the theory goes, once the transistor parameters as an amplifier is measured in this 50 ohm source and load environment, then the equations can be worked backwards to get back to Y, H, Z or whatever parameters desired.

The problem that arises with 50Ω "S" parameter measurements is the accuracy achievable, particularly for high impedances encountered when operating a transistor at low currents. This problem gets worse at lower frequencies where the impedances get higher. The measurement accuracy is like measuring the dimensions of a football field with a ruler. A summary of the accuracy of "S" parameters for our third overtone oscillator is as follows:

S_{11}	=	Moderate accuracy
S_{12}	=	Moderate accuracy
S_{21}	=	Moderate accuracy
S_{22}	=	Very poor accuracy for r_{ce}

As an example of what happens when "S" parameter are measured and converted to "Y" parameter, it very often happens that the "Y" parameter result yields a negative resistance for the output resistance. This is because the output resistance is very high, $\approx 50K$, and the measurement is right on the outer edge of the Smith chart. The difference between $50K$ and $-50K$ on the Smith chart is nearly indistinguishable.

The results from "S" parameter can be supplemented by additional measurements and assumptions about the transistor.

The feedback parameter is mainly caused by C_{cb} which can be accurately measured by a 1 mHz L.C.R. meter. Take particular care in biasing the base-to-collector junction with the same reverse bias potential that will be seen in the circuit since the C_{cb} drops exponentially as the reverse bias voltage is increased. For pagers, the collector to base bias is very nearly zero volts.

Since the parallel output resistance is so high it can be generally ignored and the S_{22} used to extract only the output capacitance.

**S Parameter to Y Parameter
Conversion ($Z_0 = 50\Omega$)**

$$Y_{11} = \frac{(1 + S_{22})(1 - S_{11}) + S_{12} S_{21}}{(1 + S_{11})(1 + S_{22}) - S_{12} S_{21}} \cdot \frac{1}{50\Omega}$$

$$Y_{12} = \frac{-2 S_{12}}{(1 + S_{11})(1 + S_{22}) - S_{12} S_{21}} \cdot \frac{1}{50\Omega}$$

$$Y_{21} = \frac{-2 S_{21}}{(1 + S_{11})(1 + S_{22}) - S_{12} S_{21}} \cdot \frac{1}{50\Omega}$$

$$Y_{22} = \frac{(1 + S_{11})(1 - S_{22}) + S_{12} S_{21}}{(1 + S_{11})(1 + S_{22}) - S_{12} S_{21}} \cdot \frac{1}{50\Omega}$$

TWO PORT PARAMETER TO HYBRID Π MODEL

$$Y_{11} = \frac{i_1}{v_1} \quad \Delta v_2 = 0 \quad \text{Input Admittance}$$

$$Y_{12} = \frac{i_1}{v_2} \quad \Delta v_1 = 0 \quad \text{Reverse transfer admittance}$$

$$Y_{21} = \frac{i_2}{v_1} \quad \Delta v_2 = 0 \quad \text{Forward transfer admittance}$$

$$Y_{22} = \frac{i_2}{v_2} \quad \Delta v_1 = 0 \quad \text{Output admittance}$$

For common emitter transistor @ $f < \frac{f_t}{100}$ the following approximations are accurate.

$$C_{cb} = \frac{-\operatorname{Im}[Y_{12}]}{W} \quad \text{typ. } .7 \text{ to } 1.2 \text{ pf}$$

$$C_{be} = \operatorname{Im}[Y_{11}] - C_{cb} \quad \text{typ. } 4 \text{ to } 7 \text{ pf}$$

$$r_{be} = \frac{1}{\operatorname{Re}[Y_{11}]} \quad \text{typ. } 1.5K \text{ to } 3 \Omega$$

$$g_m = Y_{21} \quad \text{typ. } [g_m] \quad 20 \text{ to } 40 \text{ mmhos}$$

$$C_{ce} = \frac{\operatorname{Im}[Y_{22}] - C_{cb}}{W} \quad \text{typ. } 1 \text{ pf to } 1.3 \text{ pf}$$