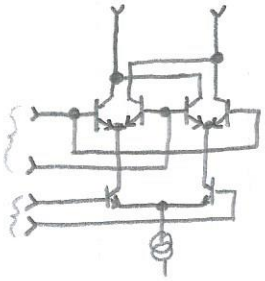
W2AEW

THE GILBERT CELL



- NAMED AFTER BARRIE GILBERT (TEKTRONIX, ANALOG DEVICES, PLESSEY)
- EXTENSIONS ON CIRCUIT FIRST PUBLISHED BY HOWARD JONES IN 1963, US PATENT 3,241,078 (1966)

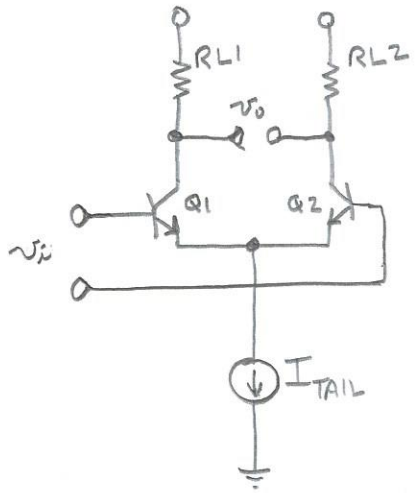
USES & APPLICATIONS

- FOUR QUADRANT ANALOG MULTIPLIER
- VARIABLE GAIN AMPLIFIER
- AUTOMATIC GAIN CONTROL CIRCUITS
- BALANCED MODULATOR
- FREQUENCY MIXER
- PHASE DETECTOR

PRE REQUISITE

#193: BACK TO BASICS: THE DIFFERENTIAL AMPLIFIER, AKA LONG-TAILED PAIR, DIFF-PAIR

FOUNDATION: THE DIFFERENTIAL AMPLIFIER (REVIEW VIDEO #193)



WHEN $v_i = 0$: $I_{C1} = I_{C2} = \frac{I_{TAIL}}{2}$

$V_{RL1} = V_{RL2}$, SO $v_o = 0$

SMALL SIGNAL DIFFERENTIAL GAIN

$$A_{V_{DIFF}} = \frac{v_o}{v_i} = g_m R_L \qquad v_o = v_i \cdot g_m \cdot R_L$$

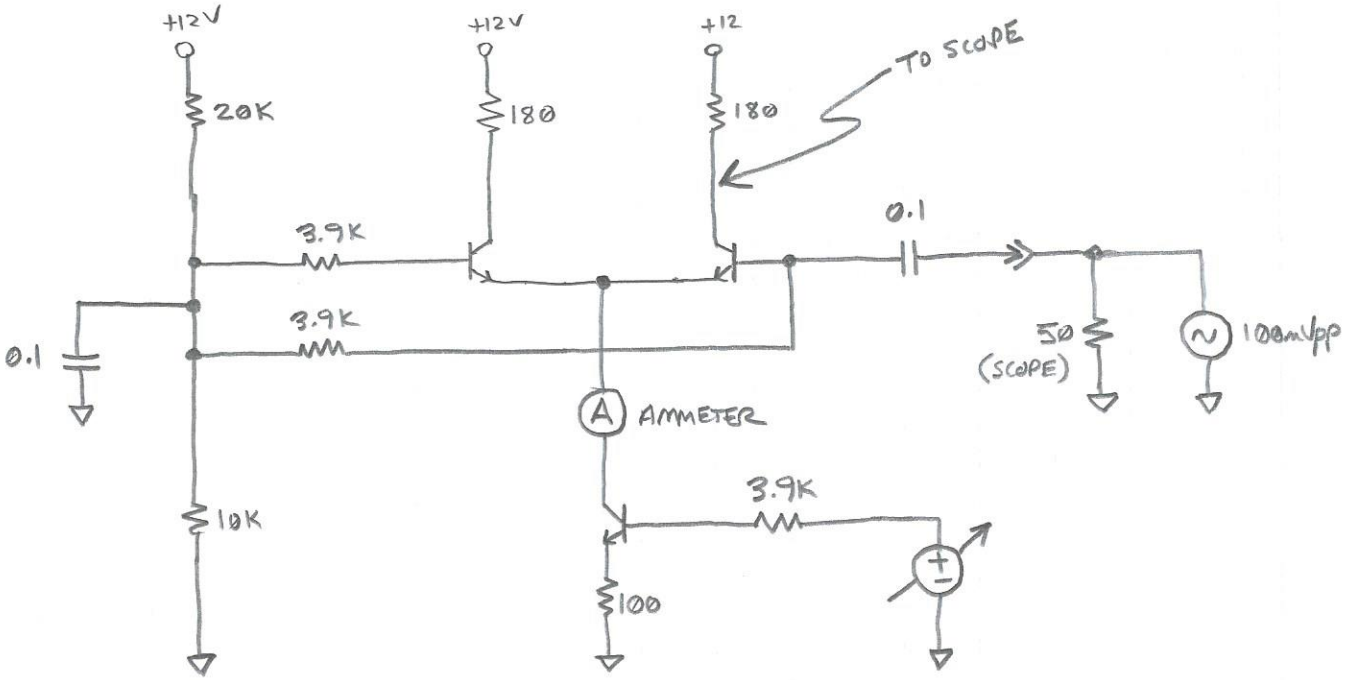
$$g_m = I_C / V_T = \left(\frac{I_{TAIL}}{2}\right) / V_T$$

V_T = 26mV @ ROOM TEMP

KEY POINT: GAIN IS A FUNCTION OF I_C

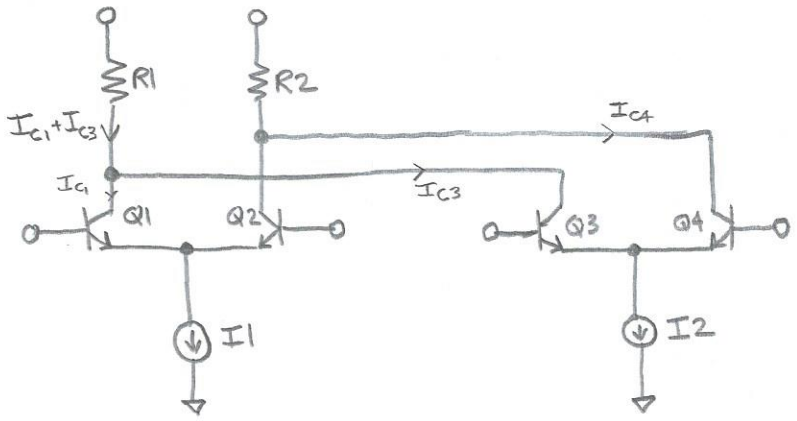
↑ REMEMBER THIS FOR LATER!

TEST CIRCUIT TO SHOW DIFF-AMP GAIN VS. TAIL CURRENT



ALL TRANSISTORS 2N3904

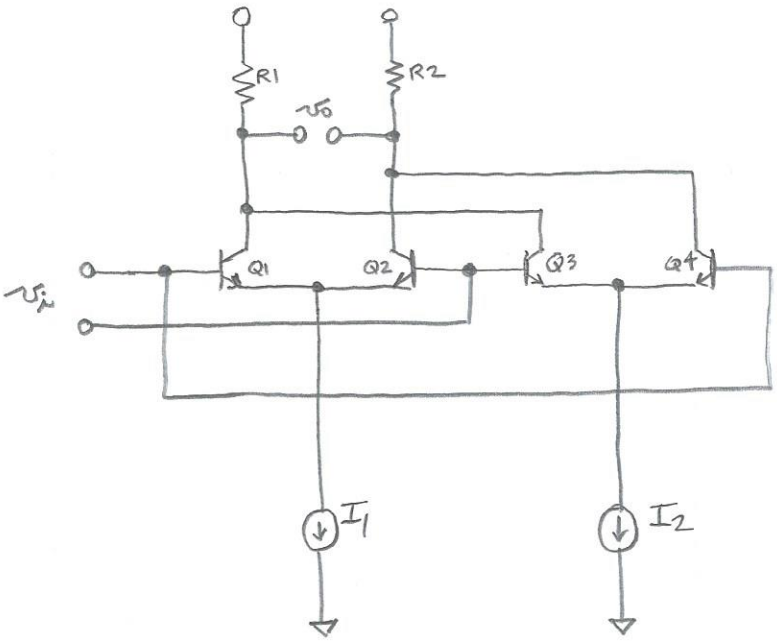
SUMMING THE OUTPUTS OF TWO DIFF-PAIRS



$$V_{R1} = I_{C1} \cdot R1 + I_{C3} \cdot R1$$

$$V_{R2} = I_{C2} \cdot R2 + I_{C4} \cdot R2$$

NEXT, EXAMINE WHAT HAPPENS WHEN WE CROSS-CONNECT THE INPUTS...



IF $I_1 = I_2$: $V_{R1} = V_{R2}$

$v_o = 0$

REGARDLESS OF v_i

IF $I_1 \neq I_2$: v_o WILL VARY $\propto v_i$

DIFFERENTIAL GAIN IS PROPORTIONAL TO THE DIFFERENCE BETWEEN I_1 & I_2

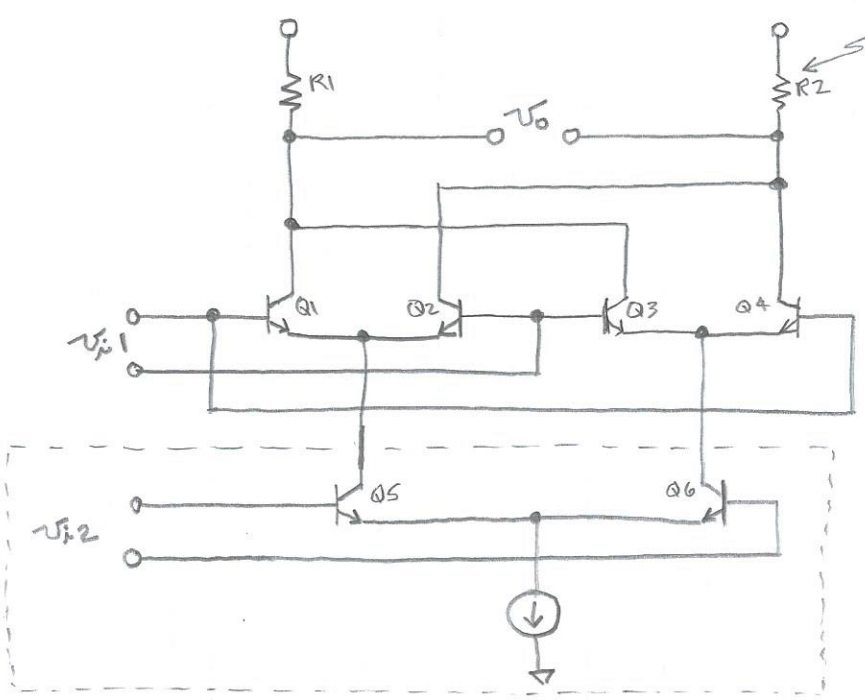
- INVERTING OR NON-INVERTING
- VARIABLE GAIN

$$v_o = K v_i$$

↑ $\propto$ DIFFERENCE IN I_1 & I_2
CAN BE + OR -

FINAL STEP: REPLACE I_1 & I_2 WITH A DIFF-PAIR

W2AEW



$$v_o \approx K \cdot v_{i1} \cdot v_{i2}$$

IF $v_{i1} = 0$, $v_o = 0$

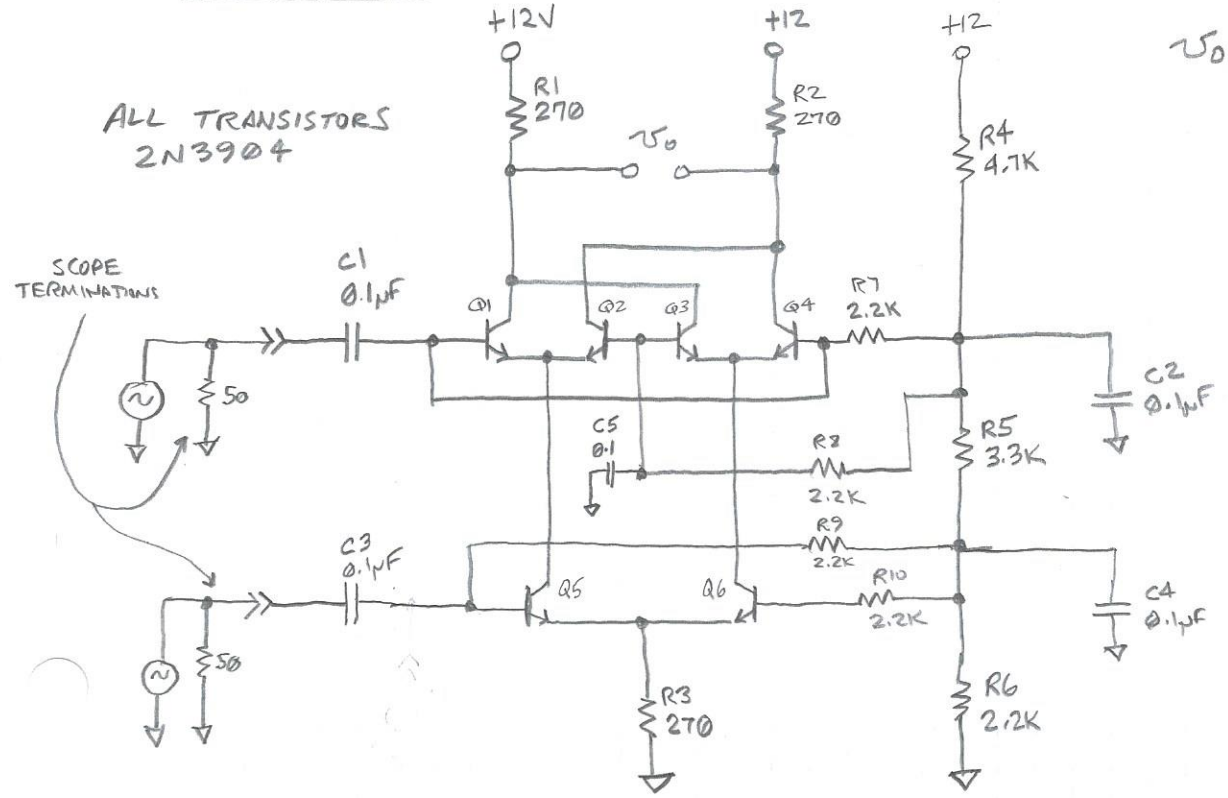
IF $v_{i2} = 0$, $v_o = 0$

THIS IS THE FUNDAMENTAL GILBERT CELL

FOUND IN NUMEROUS INTEGRATED CIRCUITS WCLUDING:

NE602
NE612
MC1496

TEST CIRCUIT



$$v_o = V_{R1} - V_{R2}$$