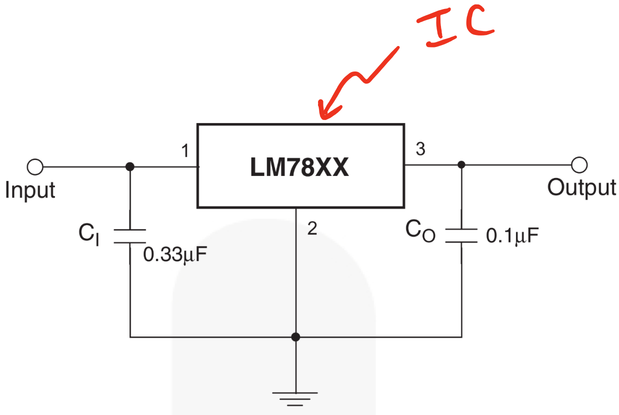
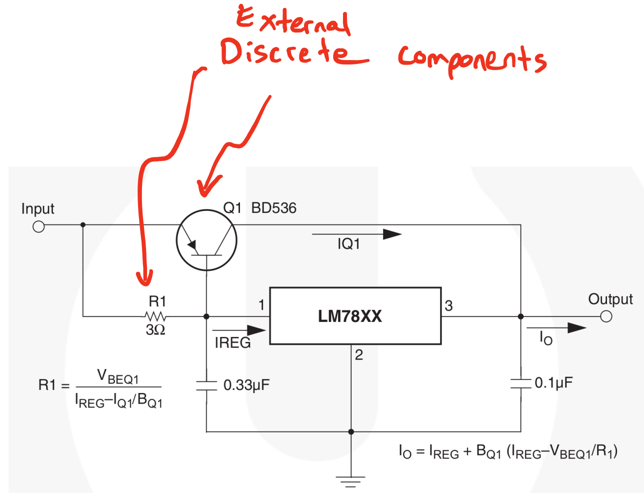


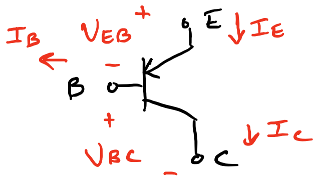
Fixed voltage regulator



High-current fixed voltage regulator

March 4, 2016

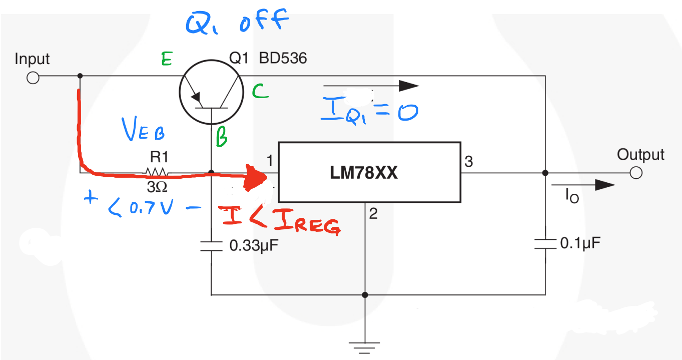
Recall: For PNP transistor

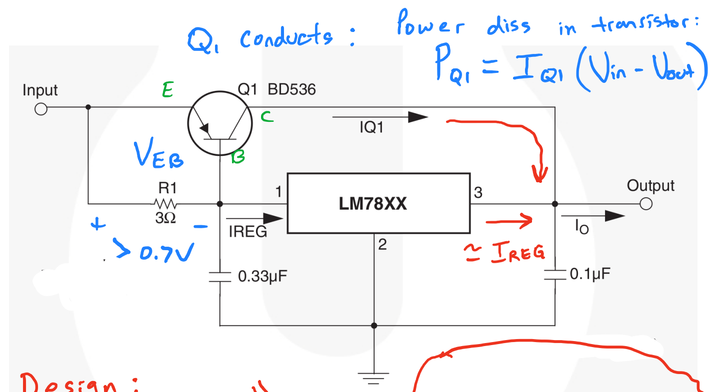


$$I_C \simeq I_S e^{V_{EB}/V_T}\left(1+\frac{V_{EC}}{V_A}\right)$$

$$I_C = \beta I_B$$

$$I_E = I_B + I_C = (\beta+1) I_B$$





I_{REG} = highest power that regulator can handle internally.

Design:

$$\frac{V_{EB}}{R_1} = \cancel{I_B} + I_{REG}$$

small

Choose:

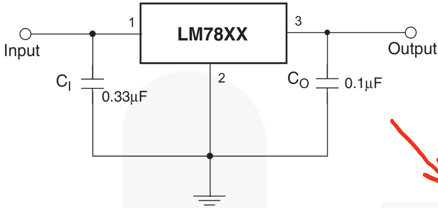
$$\boxed{R_1 = \frac{V_{EB}}{I_{REG}} \simeq \frac{0.7V}{I_{REG}}}$$

Notes

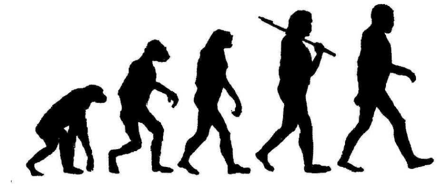
Q. Why didn't designers simply integrate Q_1 into IC itself?

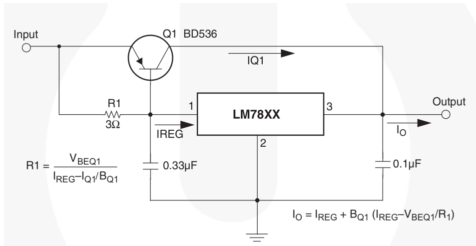
A. Expense/bulk: For high current Q_1 may need to be a power transistor w/ its own heat sink.

R_1 acts as current sensor... It is small and therefore has negligible effect on circuit performace... It generates voltage which is proportional to current. When current reached a specified value such that the generated voltage is 0.7V the transistor turns on, and bypasses the excess current.

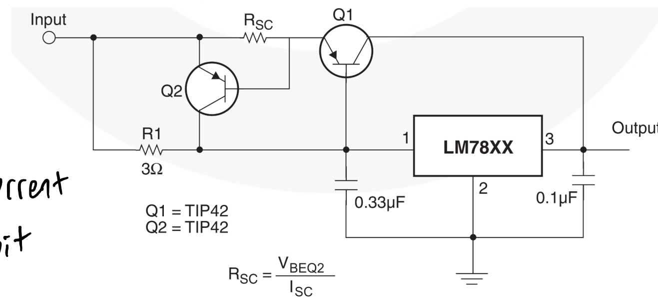


Fixed voltage regulator



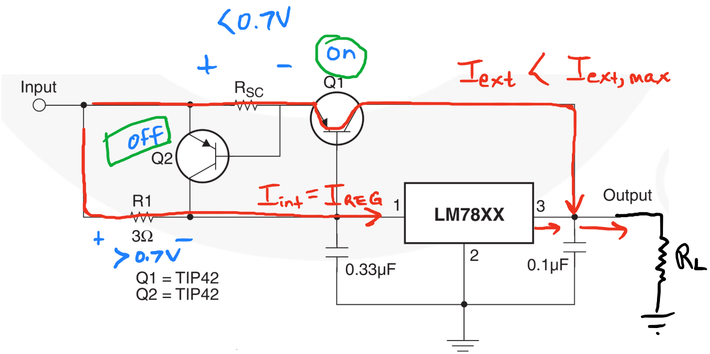


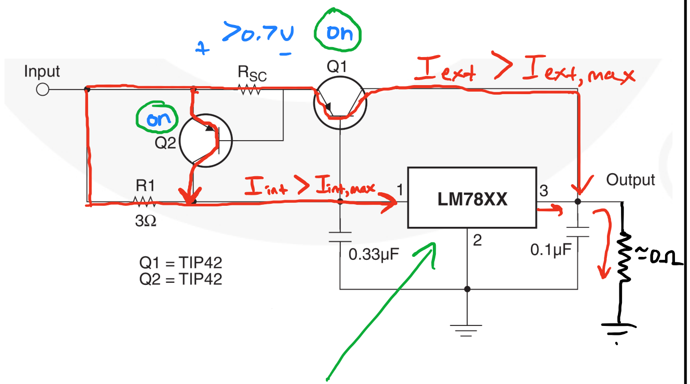
High output current



High output current + short circuit protection

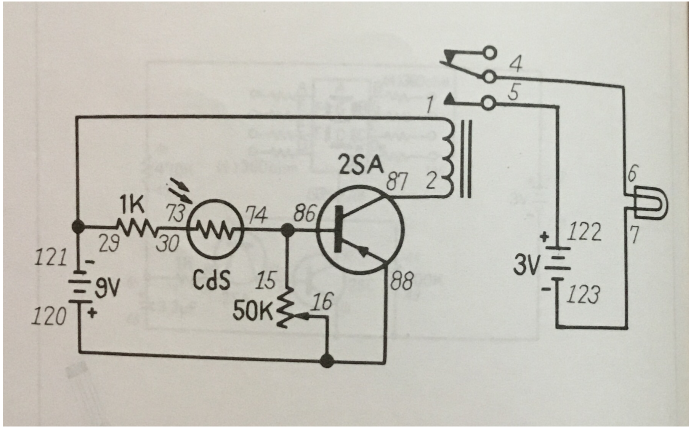
March 5, 2016





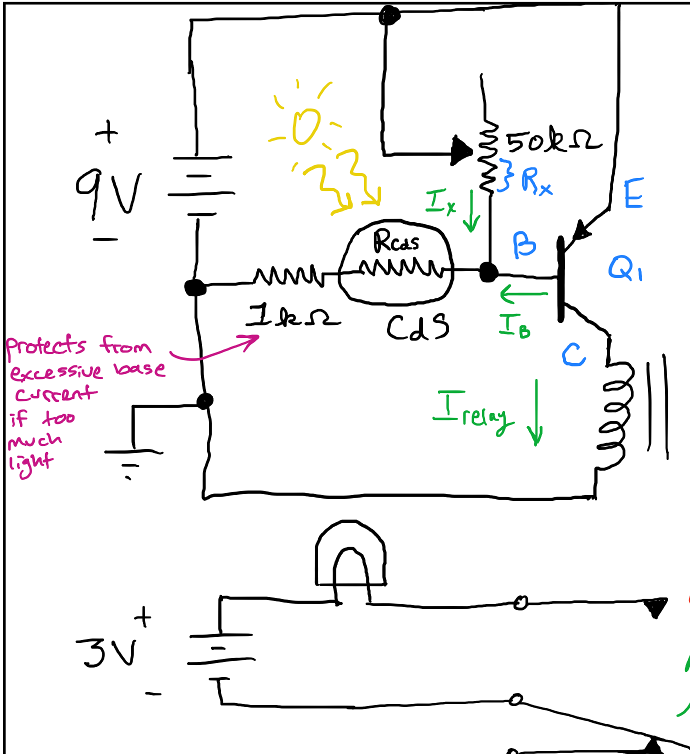
$$R_{sc} \simeq \frac{0.7}{I_{ext,max}}$$

Internal regulator current is excessive, forcing the regulator into thermal shutdown.



Experiment 78: Light controlled switch with CDS cell

March 6, 2016



$$CdS \simeq \begin{cases} \infty\ \Omega \leftarrow \text{Total Darkness} \\ \text{Somewhere in middle} \leftarrow \text{room lighting} \\ 100 - 200\ \Omega \leftarrow \text{Sun} \end{cases}$$

$$\text{Relay:} \begin{cases} |I_{relay}| < 40\text{mA} & \text{off} \\ |I_{relay}| \geq 40\text{mA} & \text{on} \end{cases}$$

Circuit analysis

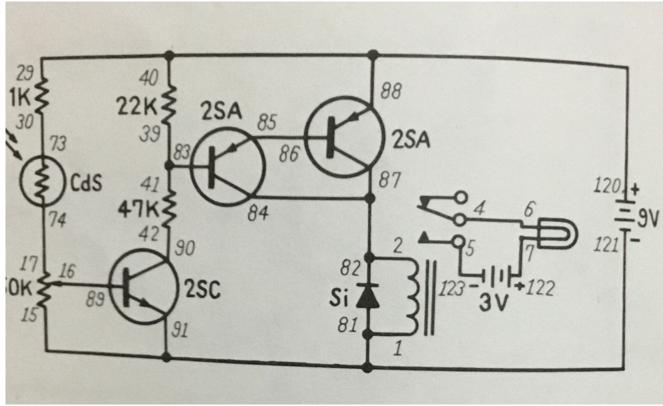
Q_1 OFF ($I_{relay} = 0$): $I_x R_x < 0.7V \rightarrow \dfrac{9}{1k\Omega + R_x + R_{cds,dark}} < 0.7V$

Q_1 on: $\dfrac{9}{1k\Omega + R_x + R_{cds,light}} = 0.7V \rightarrow V_B = 8.3V$

$$I_B = \frac{0.7V}{R_x} + \frac{8.3V}{1k\Omega + R_{cds,light}}$$

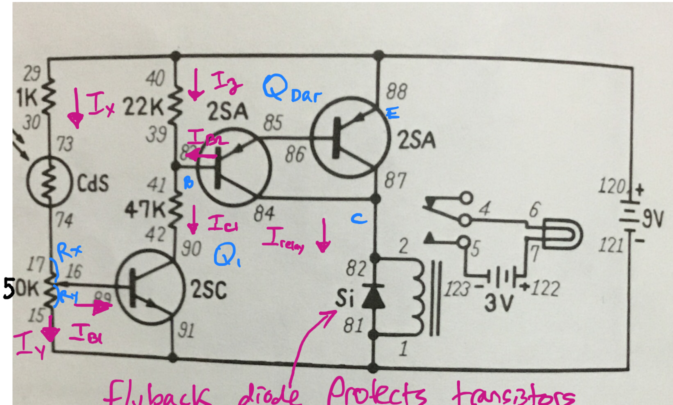
$$I_{relay} = \beta I_B$$

switches shut when $|I_{relay}| \geq 40mA$



Experiment 80:
Sensitive Light controlled switch with CDS cell

March 7, 2016



flyback diode protects transistors

Circuit analysis

(1)

Assume Q_1 is off:

$I_y R_y < 0.7V$

$I_y \approx I_x = \frac{9V}{1k\Omega + R_{cds} + 50k\Omega}$

∴ Q_1 is off when: R_y is adjustable!

$$R_{cds} > \frac{(9V)(R_y)}{0.7V} - 51k\Omega$$

R_{cds} is large in darkness!

When Q_1 is off, Q_{DAR} must also be off.

Assume Q_1 is on: (2)

$I_y R_y \approx 0.7V \rightarrow I_y = 0.7V/R_y$

$$I_x = \frac{8.3V}{1k\Omega + R_{cds} + 50k\Omega - R_y}$$

$I_{B1} = I_x - I_y$ ← $R_{cds}\downarrow$ $I_{B1}\uparrow$

$I_{C1} = \beta_1 I_{B1}$

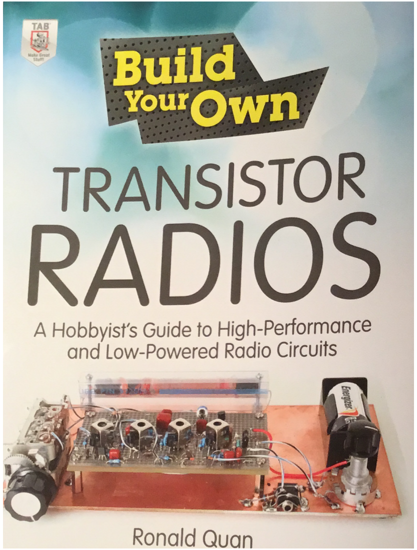
Assume Q_{DAR} is also on:

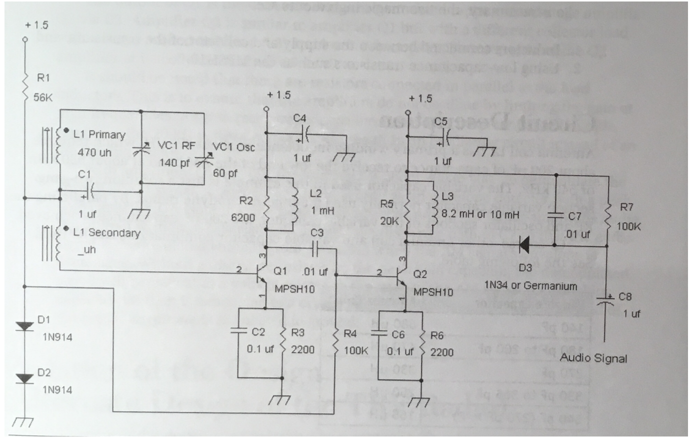
$I_z = \frac{7.6V}{22k\Omega} \rightarrow I_{B2} = I_{C1} - I_z$

$I_{relay} = \beta_{dar} I_{B2} = \beta_{dar}(I_{C1} - I_z)$

β_{dar} is big!

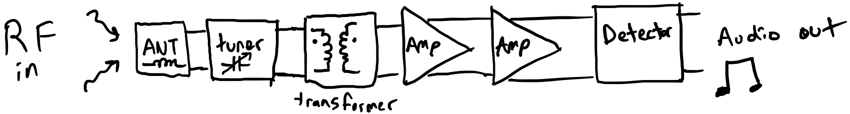
Basic operation:  $\uparrow$ $R_{cds}\downarrow$ $I_{B1}\uparrow$ $I_{C1}\uparrow$ $I_{relay}\uparrow$





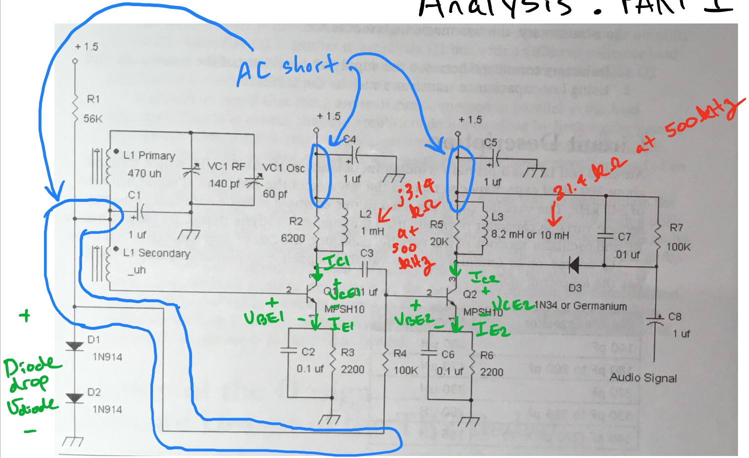
Low powered tuned resonant frequency (TRF) AM radio receiver

Block diagram:



March 8, 2016

Analysis : PART 1



DC Quiescent Point – Assume Q_1 & Q_2 are in active region.

I_{C1} :

$$V_{diode} - V_{BE} \simeq (\underbrace{I_{E1}}_{\simeq I_{C1}})(2200)$$

$$\therefore \; I_{C1} \simeq \frac{V_{diode} - V_{BE}}{2200}$$

V_{CE1} :

$$V_{CE1} = 1.5V - (I_{E1})(2200)$$

$$\therefore \; V_{CE1} = 1.5 - V_{diode} + V_{BE}$$

I_{C2} :

$$V_{diode} - \frac{I_{C2}\cdot 100k}{\beta} - V_{BE2} \simeq I_{C2}\cdot 2.2k$$

$$\therefore \; I_{C2} \simeq \frac{V_{diode} - V_{BE2}}{2200 + \frac{100k\Omega}{\beta}}$$

V_{CE2} : $1.5V - (I_{E2})(2200)$

$$\therefore \; V_{CE2} = 1.5V - \left(\frac{V_{diode} - V_{BE2}}{2200 + \frac{100k\Omega}{\beta}}\right)2200$$

Numerical Example

$$\left.\begin{array}{l} V_{diode} = 0.76\,VDV \\ V_{BE1} = V_{BE2} = 0.55\,VDC \\ \beta = 100 \end{array}\right\}$$

$$I_{C1} = \frac{0.76 - 0.55}{2200} \simeq 0.1\,mA\,DC$$

$$I_{C2} = \frac{0.76 - 0.55}{2200 + \frac{100E3}{100}} \simeq 0.07\,mA\,DC$$

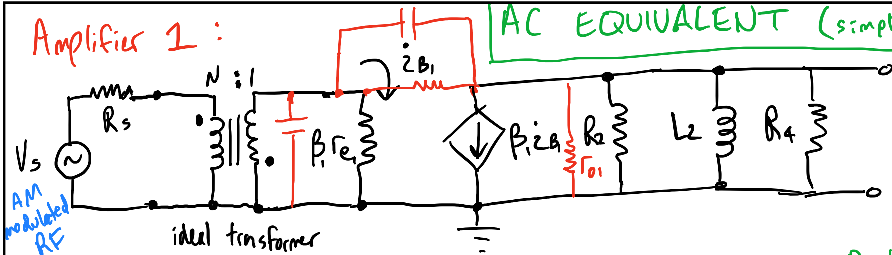
$$V_{CE1} = 1.5 - 0.76 + 0.55 \simeq 1.3\,VDC$$

$$V_{CE2} \simeq 1.36\,VDC$$

ANALYSIS PART 2

AC EQUIVALENT (simplified)

Amplifier 1 :

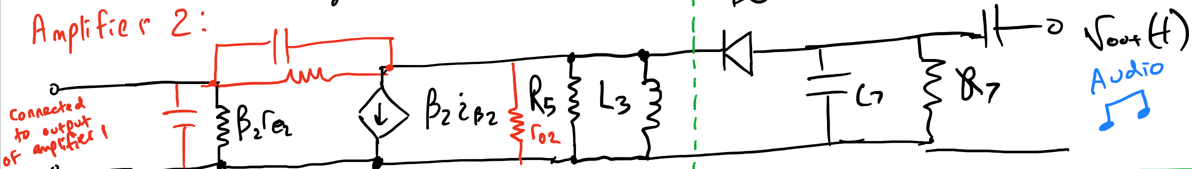


ideal transformer

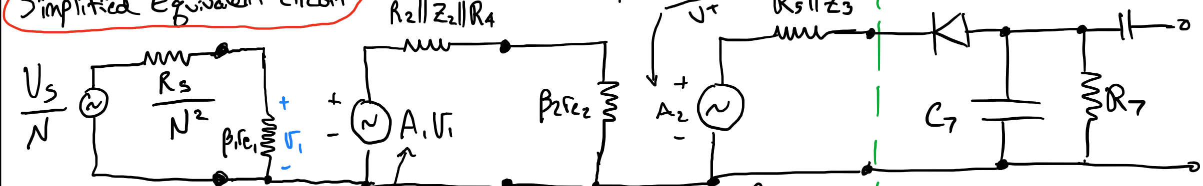
$$N = \sqrt{\frac{L_{primary}}{L_{secondary}}}$$

connected to input of amplifier 2 . . .

Amplifier 2 :



Simplified Equivalent circuit



$$A_2 = -\frac{R_5 \| Z_3}{V_T} I_{CQ2}$$

$$A_1 = \frac{-R_2 \| Z_2 \| R_4}{r_{e1}} = \frac{-R_2 \| Z_2 \| R_4}{V_T} I_{CQ1}$$

Numerical example

ANALYSIS PART 3

$I_{CQ_1} = 0.1\,mA$

$I_{CQ_2} = 0.07\,mA$

$f = 500\,kHz$

$R_2 = 6.2\,k\Omega$

$R_4 = 100\,k\Omega$

$Z_2 = j\omega L_2 = j\,3.14\,k\Omega$

$R_2 \parallel R_4 \parallel Z_2 \simeq 2.76\,k\Omega \angle 62^\circ$

$\beta_2 r_{e2} = \beta_2 \dfrac{V_T}{I_{CQ_2}} = (100)\dfrac{26}{0.07} = 37.14\,k\Omega$

$R_5 = 20\,k\Omega \quad Z_3 = j\omega L_3 = j\,31.4\,k\Omega$

$R_5 \parallel Z_3 = 16.87\,k\Omega \angle 32.48^\circ$

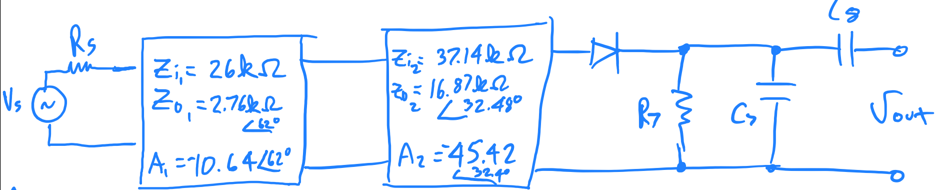
$\beta_1 = \beta_2 = 100$

$\beta_1 r_{e1} = \beta_1 \dfrac{V_T}{I_{CQ_1}} = (100)\dfrac{26}{0.1} = 26\,k\Omega$

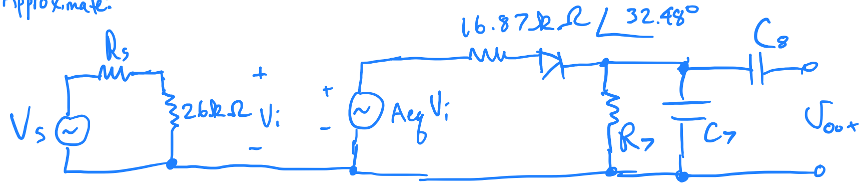
$A_1 = -\dfrac{2.76\,k\Omega \angle 62^\circ}{V_T} I_{CQ_1} = -10.64 \angle 62^\circ$

$A_2 = -\dfrac{R_5 \parallel Z_3}{V_T} I_{CQ_2}$

$= -45.42 \angle 32.48^\circ$



Approximate:



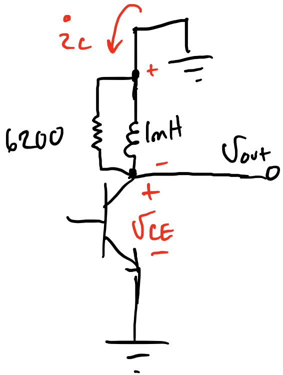
$A_{eq} = \dfrac{Z_{i2}}{Z_{o1} + Z_{i2}} A_1 A_2 \cong 469 \angle 91^\circ$

Verified to be "pretty accurate" with LTspice.

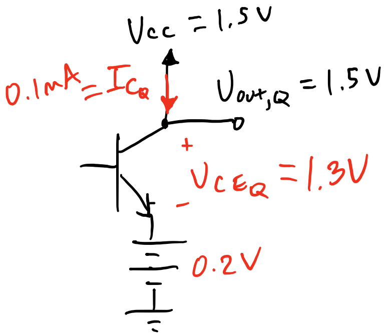
Large gain! & $\simeq 90^\circ$ phase shift

Cut-off / Saturation

Eventually input will be so big that it will drive the BJT into cut-off or saturation. This causes the output to clip. Lets find the min/max values of v_{out} before clipping sets in.



First CE amplifier AC equivalent



First CE amplifier DC equivalent

$\boxed{\text{SATURATION}}$ ← $V_{CE} \cong 0.2V$

total ↓, DC ↓, AC

$$V_{CE} = V_{CEQ} + v_{CE}$$

$$V_{CE} = 1.3V + v_{CE}$$

Saturation : $V_{CE} \simeq 0.2$ ← total V_{CE}

$$\longrightarrow v_{CE}^{-} = -1.1 V$$

∴ BJT saturates when $v_{CE} = v_{CE}^{-} = -1.1V$

$\boxed{\text{CUT-OFF}}$ ← $I_C \simeq 0$

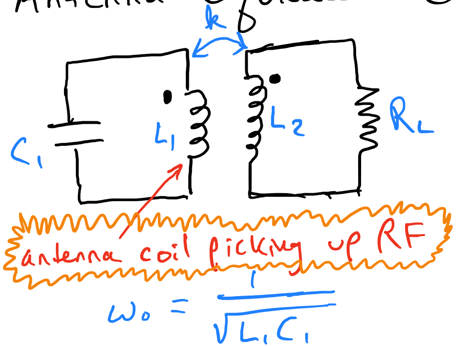
$$\frac{v_{CE}^{+}}{Z_c} = I_{CQ} \longrightarrow v_{CE}^{+} = Z_c I_{CQ} = 0.28V$$

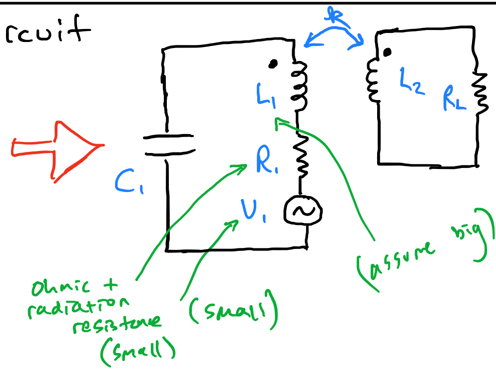
$2800\angle 63.14°$

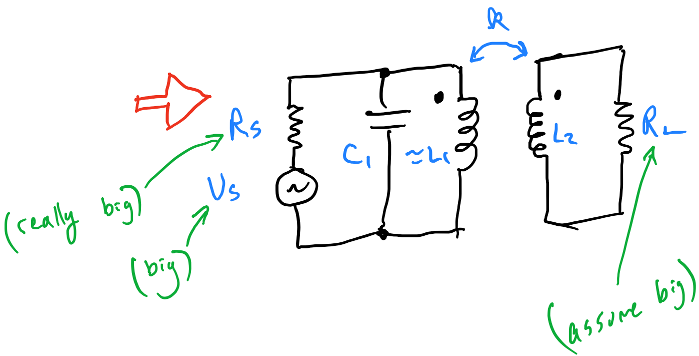
currents exactly cancel each other out

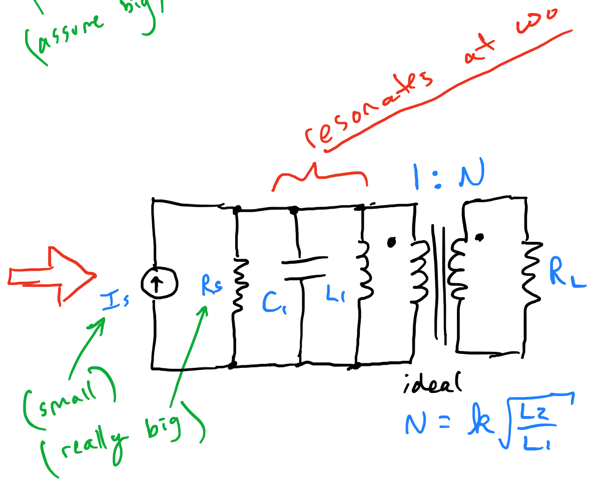
∴ BJT is cut-off when $v_{CE} = v_{CE}^{+} = 0.28V$

Antenna Equivalent Circuit



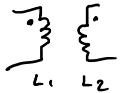






Design notes

- Inductive loading at collectors of Q_1 & Q_2 raises V_{CB} to reduce internal collector-to-base capacitances of transistors.
- Transistor was chosen to be low capacitor type
- Frequency adjusted by variable capacitor across antenna coil. Transformer step down chosen (i.e.



$L_2 << L_2$) so that AC input impedance looking into Q_1 is stepped up to increase resonant Q of antenna coil (increase selectivity).

I guess this also increases sensitivity by providing a better impedance match to the coils large equivalent shunt resistance,

- Resistors are connected in parallel with collector inductors. This is too reduce gain at high frequencies. Author says this is needed to prevent oscillations. Remove the resistors and the thing oscillates.
- Germanium diode used as envelope detector.
- Detector cap C7 is peak hold cap. R7 gives discharge path. Without R7, the voltage would be pinned or "stuck" at a voltage related to peak of AM signal, resulting in gross "failure to follow" distortion.