- **Common Emitter amplifier:—** $A_V \approx -200$, $R_{in} \approx 3k\Omega$

- **Emitter follower:—** gain about 1, R_{in} is high, R_{out} is low.

- **Push-Pull Emitter follower** gain about 1, high output current drive capability, symmetrical performance.

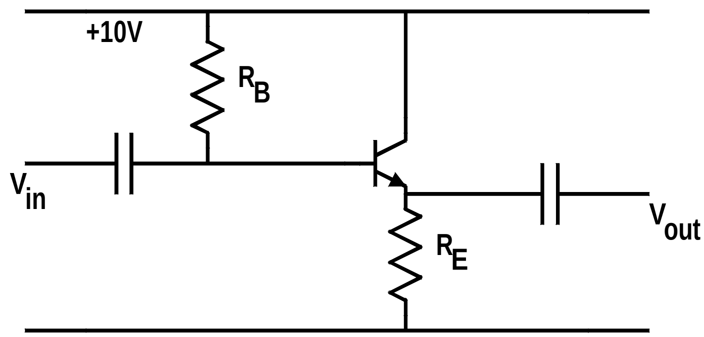
- **Differential amplifier** Amplifies DC signals.

- **Current mirror:—** nearly constant current, used as high resistance load resistor or active load.

- **Tuned amplifier:—** Frequency of max amplification determined by $f = \frac{1}{2\pi\sqrt{LC}}$

Brief treatment of the principal transistor circuit building blocks used in linear analogue circuit systems.

These circuit blocks or modules constitute a minimum set of such blocks that can be combined to form more complex circuits which have increased functionality.



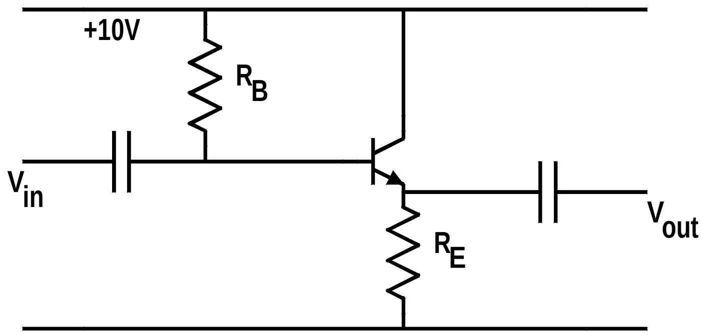
Emitter follower or common collector

Signal applied at the base changes the base voltage.

Emitter voltage follows the base voltage up or down maintaining a nearly constant emitter base voltage of 0.7V.

Voltage gain is 1 or slightly less than 1.

Analogy:– a tow truck and trailer.



Input impedance of the emitter follower
Input voltage v_{in} gives v_b which gives i_b.
Current across the emitter base junction and in R_E is $i_e = \beta i_b$.
This gives a base voltage

$$v_b = i_e \left(\frac{25mV}{I_E} + R_E \right) = \beta i_b \left(\frac{25mV}{I_E} + R_E \right)$$

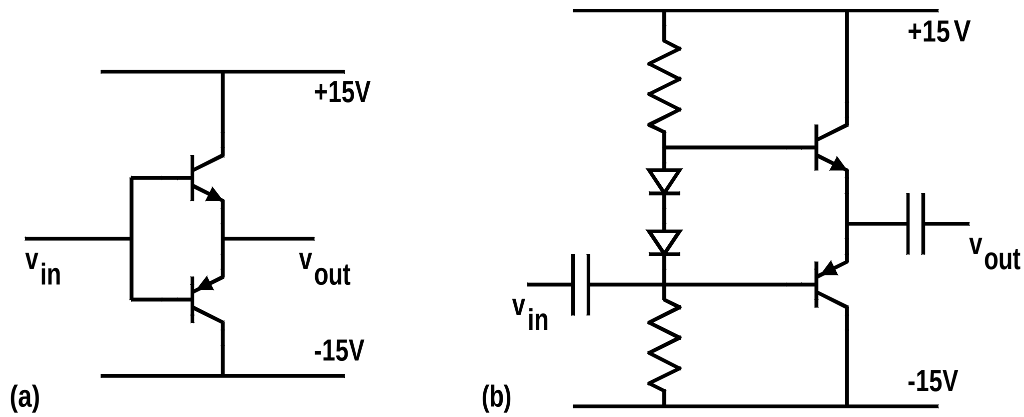
$$\text{giving} \quad R_{in} = \frac{v_{in}}{i_{in}} = \frac{v_b}{i_b} = \beta \left(\frac{25mV}{I_E} + R_E \right)$$

typically $R_E \gg \frac{25mV}{I_E}$
Input resistance of emitter follower of the order of $250 \times 1k\Omega = 250k\Omega$.

High input resistance makes the circuit ideal for use as the input stage where we want to minimise the loading on sensors or other electronic pick up devices.

Also used for output stages where the high current driving capability of the circuit—its current amplification properties—make it ideal for driving low impedance loads

Loudspeakers (8 Ohms typically), small speed controlled motors and other devices which draw large currents at low voltages.



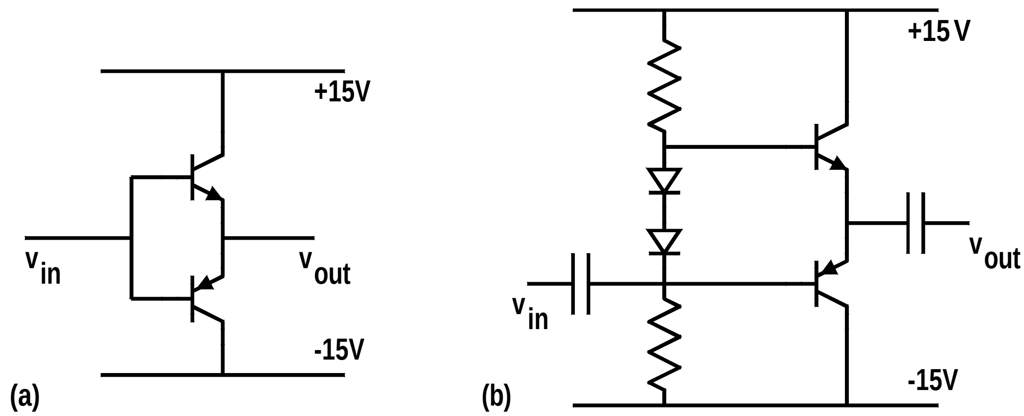
Emitter follower

npn emitter follower responds well to positive going signals

Fast, large, negative going signals can give a reverse biased emitter base junction and a turned off transistor

Poor response for negative going signals.

The reverse is true for the pnp version of the emitter follower.



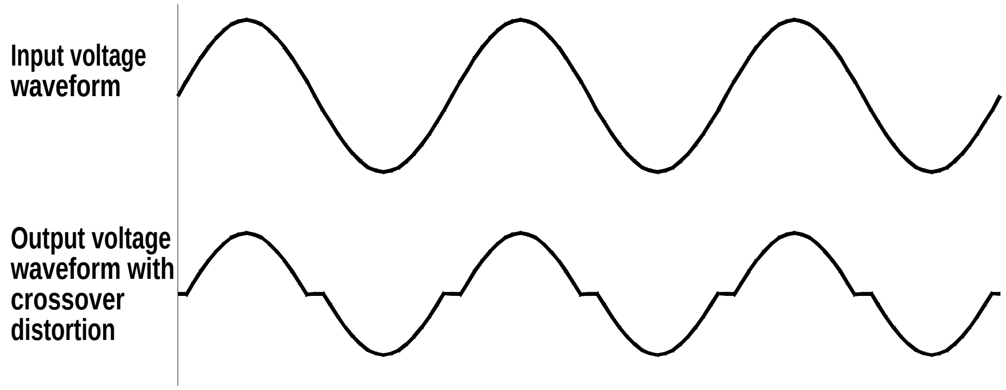
Push–Pull Emitter Follower

Use two transistors, one pnp and the other npn, in series

This gives fast response to fast input signals of either polarity

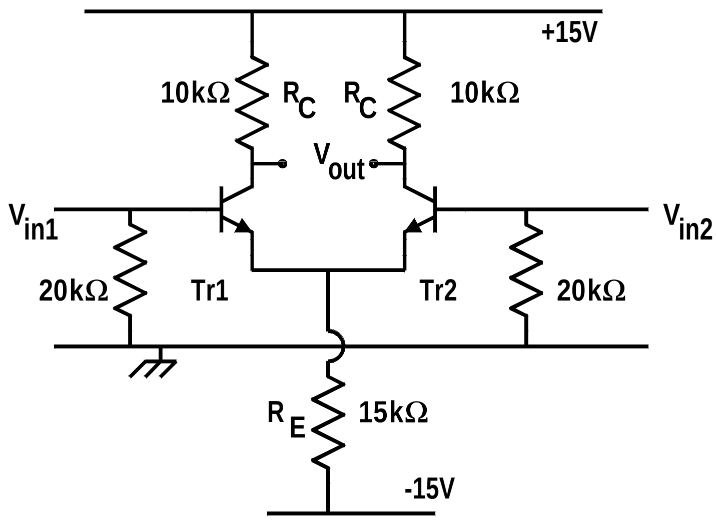
But dead spot in response due to the fact that neither transistor is conducting in central region.

Called crossover distortion



Minimise crossover distortion by providing some DC forward bias for the transistors even when when there is no input signal.

Two diodes are forward biased by the resistor chain and the emitter base junctions are maintained at $V_{BE} = 0.7V$ for each transistor.
So we no longer have the problem of both emitter followers being off for small signals and therefore the crossover distortion is eliminated.

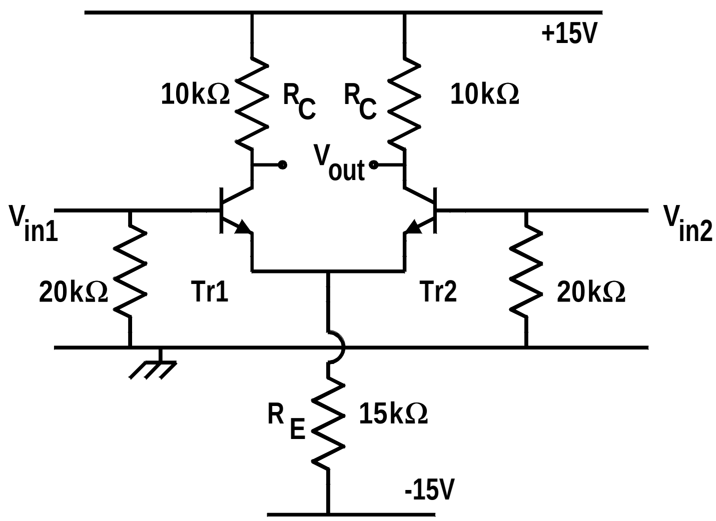


Differential amplifier

AC signals can be coupled through a capacitor without upsetting the DC bias in the transistor.

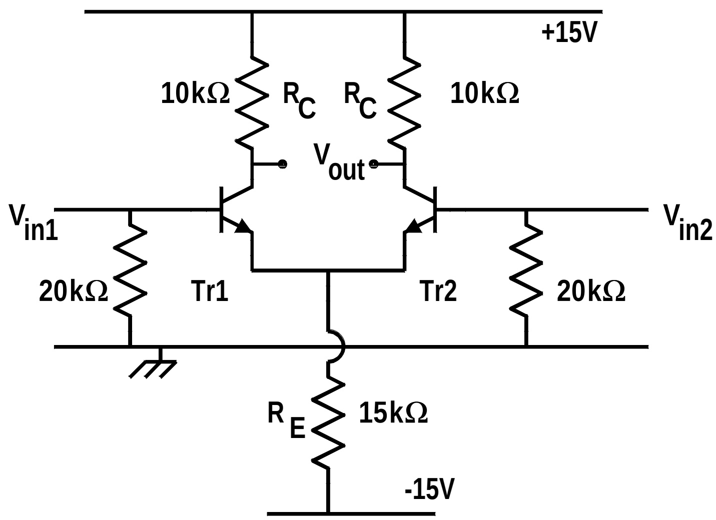
It is not possible to couple in DC signals without affecting the V_{EB} of 0.7V

To obtain DC amplification o use two transistors, balanced against each other, in what is called a differential amplifier configuration.

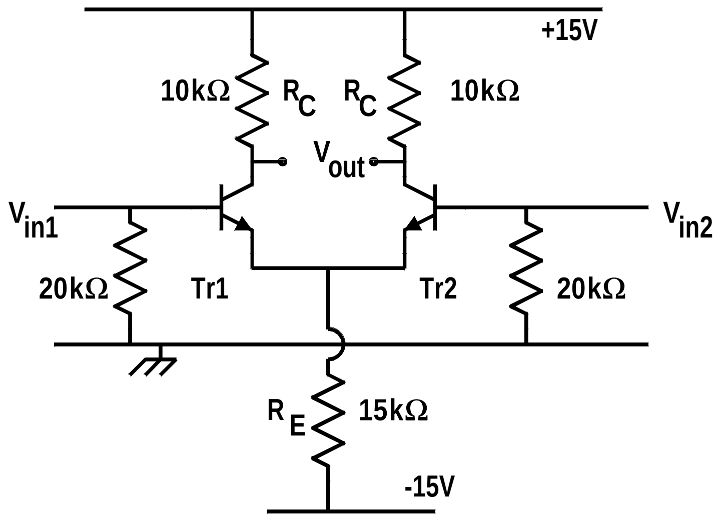


The circuit is symmetrical with a signal applied to the base of each transistor.

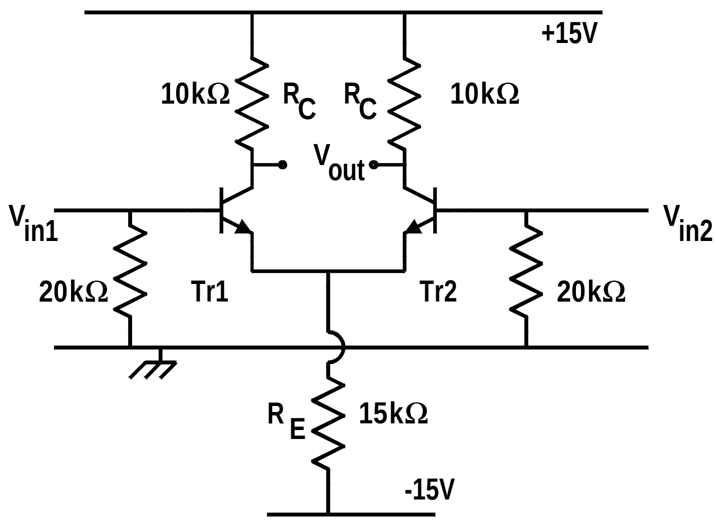
The essential principle of operation is that the two halves of the circuit are coupled together by the shared emitter resistor, R_E, of $15k\Omega$.



No input signals present current in R_E divides equally between the two transistors
Equal voltages at the two collectors and a differential output voltage between the two collectors of 0V.



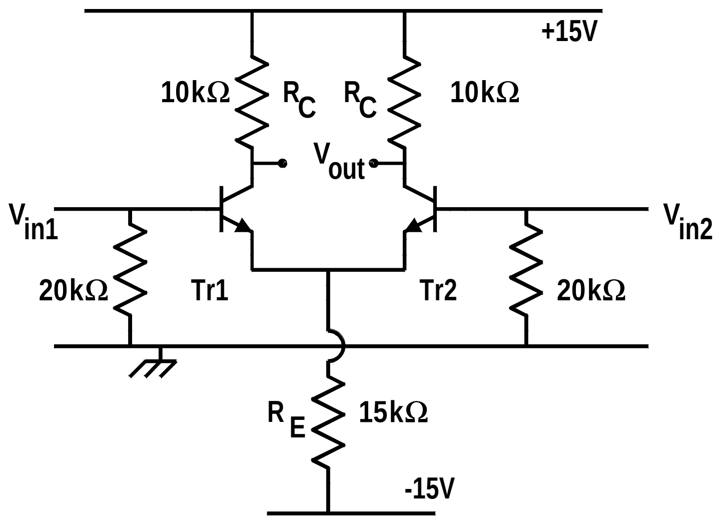
Positive voltage signal at base of left transistor gives more emitter current.
Causes current in R_E to increase due to emitter follower action
Smaller V_{EB} for the right transistor reducing the current
Voltage at collector of TR1 decreases and voltage at collector of TR2 increases
Current in R_E remains nearly constant since an increase of current through TR1 is balanced by a decrease of current through TR2.



Gain of differential amplifier.

$$0-(-15V) = I_B \times 20k\Omega + 0.7V + 2 \times I_E \times 15k\Omega$$

The emitter current of two transistors flows through R_E giving factor of 2



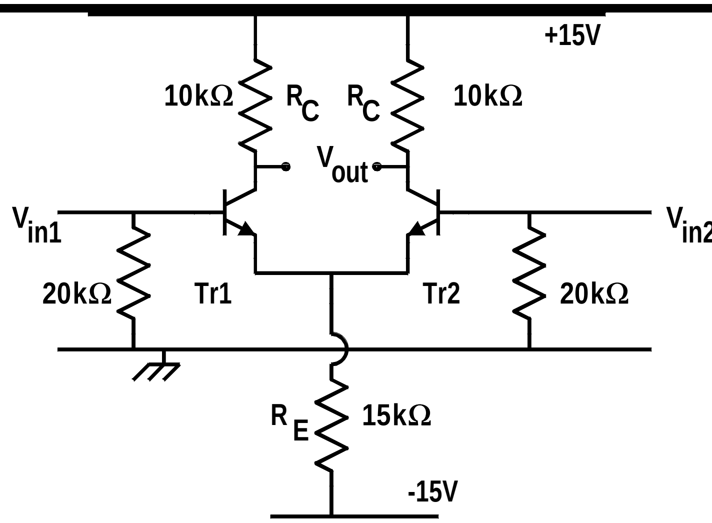
Use $I_E = \beta I_B = 300 I_B$

$14.3 = (20\times10^3+2\times300\times15\times10^3) I_B = 9.02\times10^6 I_B$

to get $I_B = 1.58\times10^{-6} = 1.58\mu A$Which gives

$$
\begin{aligned}
V_B &= -0.032V \\
V_E &= -0.032 - 0.7 = -0.732V \\
I_E &= \frac{0.95mA}{2} = 0.475mA \\
V_C &= 15V - 0.475 \times 10 \times 10^3 = 15 - 4.75 = 10.25V
\end{aligned}
$$

DC voltages and currents are determined.

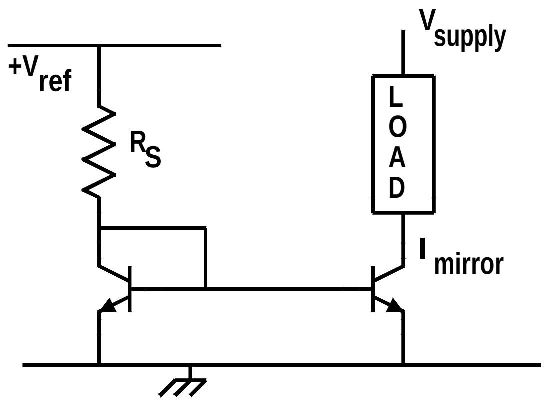


v_{in} applied to one input only is equivalent to $+\frac{v_{in}}{2}$ applied to one input and $-\frac{v_{in}}{2}$ applied to the other input due to coupling action of the shared emitter resistor.
Effect is the same as if signal were applied to a common emitter amplifier for which the amplification is $-R_C \times \frac{I_E}{25mV}$.

$$\Delta V_C = -R_C \times \frac{I_E}{25mV} \times \frac{v_{in}}{2}$$

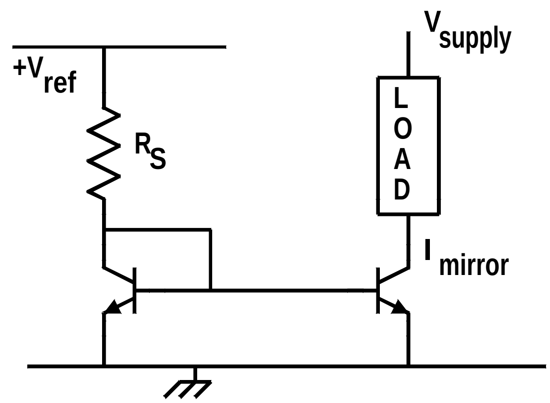
Differential voltage amplification is

$$A_V = -R_C \times \frac{I_E}{25mV}$$



Current mirror

Base current is sensitive function of the emitter–base voltage
Not normally possible to control the base current by controlling the base voltage.



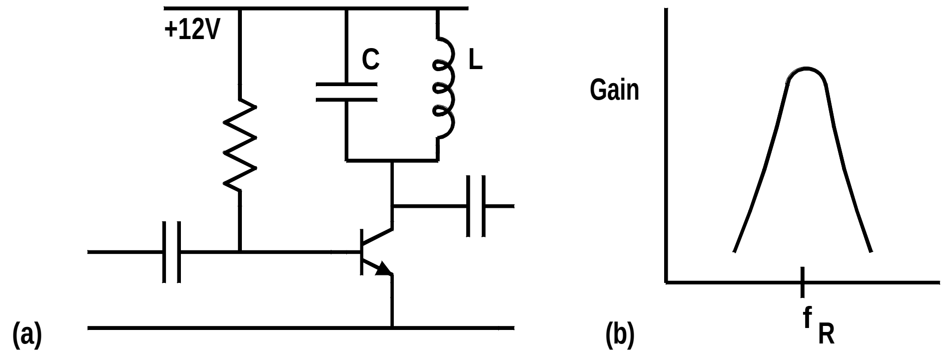
Left transistor is diode connected transistor

Voltage drop across the emitter–base junction diode is for a current of $\frac{V_{ref}-0.7}{R_S}$.

Matched transistors. Same emitter–base voltages give same collector currents.

Current in load mirrors current in the left transistor.

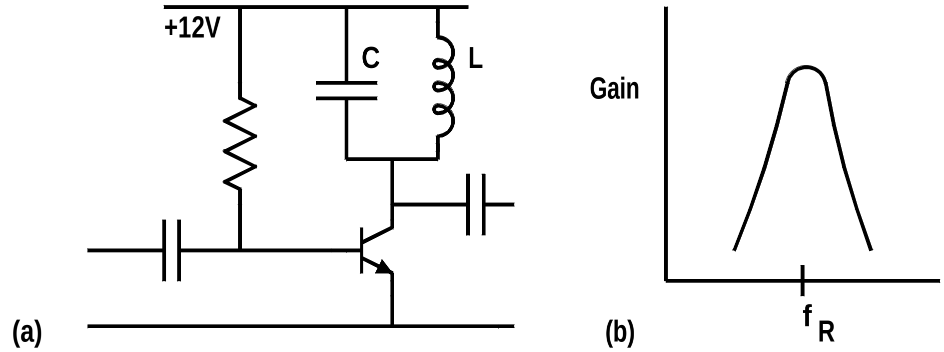
Gives constant current in the right transistor and load.



Tuned amplifier The gain of a common emitter amplifier is given by $-R_C \times \frac{I_E}{25mV}$ which is essentially independent of frequency.

Replace R_C by a resonant circuit which has a maximum impedance at one particular frequency to get a highly peaked gain versus frequency response curve.

The Q factor of the LC circuit determines the sharpness of the response



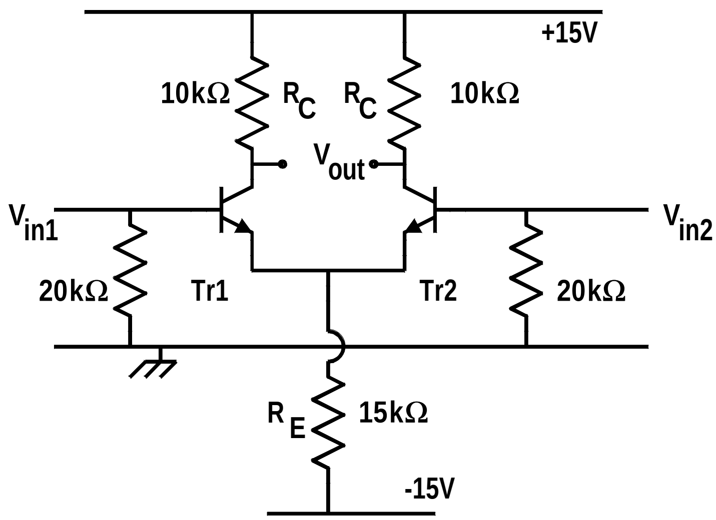
$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

Gain at the maximum depends on the resistance of the inductance and also on the input impedance of the next stage or the load.

Resonant tuned amplifier allows one particular radio frequency signal, picked up from an antenna, to be selectively amplified

Amplitude or frequency demodulation yields an audio signal in a radio receiver.

Frequency selection by using a variable capacitor for tuning.


+15V
10kΩ
R_C
R_C
10kΩ
V_{out}
V_{in1}
V_{in2}
20kΩ
Tr1
Tr2
20kΩ
R_E
15kΩ
-15V