Single Stage CE Amplifier

Group members:

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List of components:

1. Resistors: 30k ohms(R_1), 12k ohms(R_2), 2k ohms (R_e), 2.7k ohms(R_c).
2. Capacitors: 33uF(CC_1), 33uF(CC_2), 47uF(C_e).
3. BJT BC547B.

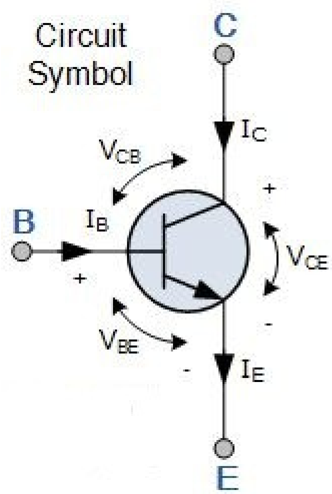
Theory:

Introduction

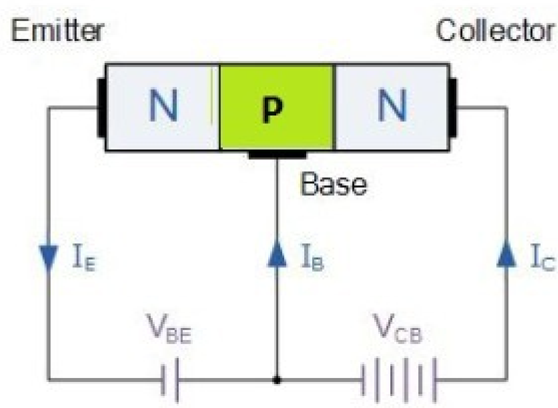
All types of transistor amplifiers operate using AC signal inputs which alternate between a positive value and a negative value so some way of "presetting" the amplifier circuit to operate between these two maximum or peak values is required. This is achieved using a process known as **Biasing**. Biasing is very important in amplifier design as it establishes the correct operating point of the transistor amplifier ready to receive signals, thereby reducing any distortion to the output signal.BC547B is the transistor

Working principle of a NPN Transistor:

The voltage between the Base and Emitter (VBE), is positive at the Base and negative at the Emitter because for an NPN Transistor, the Base terminal is always positive with respect to the Emitter.



Also the Collector supply voltage is positive with respect to the Emitter (VCE). So for a bipolar NPN Transistor to conduct the Collector is always more positive with respect to both the Base and the Emitter.



In Forward biased condition, the collector is connected to high positive voltage with respect to base i.e. VCB is very high. So C-B junction is reverse biased. VCB >> VBE. The base is connected to low positive voltage with respect to emitter i.e. VBE is low. When we increase VBE ≥ 0.7V (the value 0.7V is a typical value of potential barrier voltage) the Transistor is forward biased. Now large number of electrons in emitter layer is repelled by negative terminal of VBE and they flow towards B-E junction. They cross the junction and enter into small base layer. Here some electrons combine with holes. Also some of them are attracted by positive terminal of VBE and remaining maximum number of electrons flow into collector layer, crossing the second junction i.e. C-B junction.

The resident electrons of collector are repelled by these (guest) electrons and thus, then all the electrons are present in collector layer are attracted by positive terminal of VCB. Thus, all these electrons complete their journey back into emitter layer and produce conventional currents in the transistor as shown in the above circuit. Thus, as per Kirchhoff Current Law, we can write, IC + IB = IE. Now when VBE is still increased, more electrons are repelled by negative terminal of VBE. So base-emitter junction is more and more forward biased. Thus the base current (IB) increases, which in turn increases Ic. Hence, we can say that collector current (IC) is the function of base current (IB). But there is a typical value of VBE for each transistor, at which the collector current IC no longer remains the function of base current Ib. Also collector current is directly proportional to the base current. In all this process, maximum number of electrons from emitter layer flow into collector layer. So collector current is almost equal to emitter current. Hence we say that, collector current is proportional to emitter current.

In Reverse Biased condition, both the junctions are reverse biased as the batteries are connected in opposite direction. Due to VCB battery, the collector-base junction is reverse biased. Similarly, due to VEB battery, the base-emitter junction is also reverse biased. So charges cannot flow and current in the Transistor is practically zero. This method is not useful as the Transistor is in "cut-off" state since current is zero.

Common emitter amplifier circuit:

The most common way to use a transistor as an amplifier is a *common-emitter* circuit because the emitter is connected to ground, which means that both the input signal and the output signal share the emitter connection.

In this kind of arrangement, as the input voltage V_i increases, the base current I_B also increases which in turn increases the collector current I_C. This causes an increase in the voltage drop across the collector resistor, R_C which results in a decreased output voltage V_0as emphasized by the following relationship

$$V_0 = V_{CC} - I_C R_C$$

Similarly as the input voltage goes on decreasing, I_B and hence I_C decrease, due to which the voltage drop across R_C also decreases thereby increasing the output voltage. This indicates that for the positive half-cycle of the input waveform, one would get amplified negative half-cycle while for the negative input pulse, the output would be a amplified positive pulse. Hence there exists a phase-shift of 180º between the input and the output waveforms of the common emitter amplifier

The aim of any small signal amplifier is to amplify all of the input signal with the minimum amount of distortion possible to the output signal, in other words, the output signal must be an exact reproduction of the input signal but only bigger (amplified).

In order to obtain an undistorted amplified version of the input waveform, nothing but faithful amplification, transistor needs to be biased properly by setting a suitable operating point (Q-point).

The single stage common emitter amplifier circuit shown above uses what is commonly called "Voltage Divider Biasing". This type of biasing arrangement uses two resistors as a potential divider network across the supply with their center point supplying the required Base bias voltage to the transistor. Voltage divider biasing is commonly used in the design of bipolar transistor amplifier circuits.

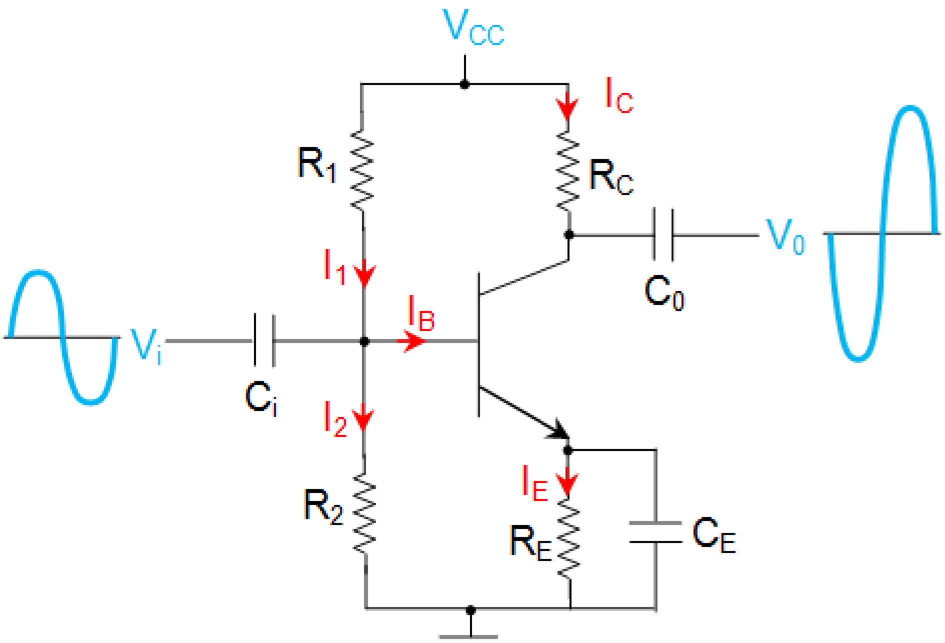


Figure 2 Common Emitter Amplifier with Biasing and Decoupling Details

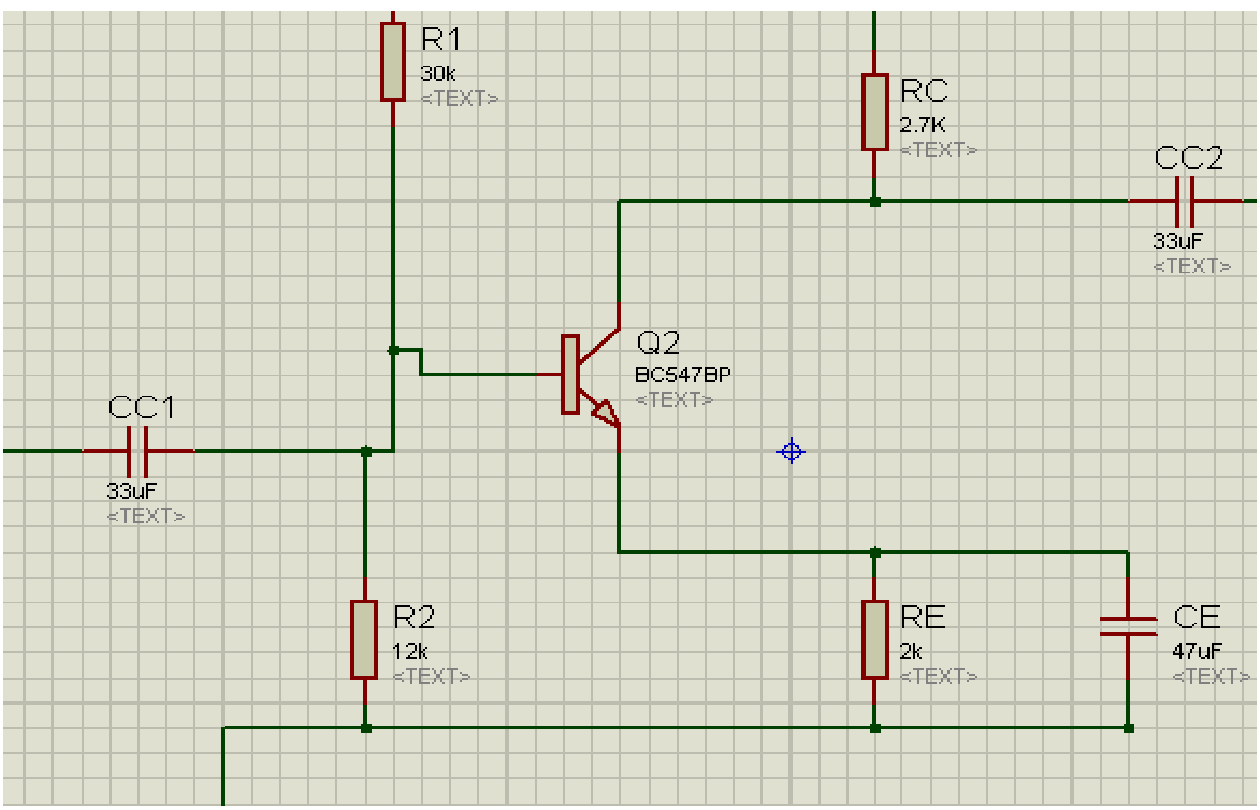
The resistors R1 and R2 are used to provide bias for the base of the transistor (voltage-divider transistor biasing) while the emitter resistor RE is used to ensure that proper DC conditions are maintained for the circuit by regulating the amount of DC feedback. Further the circuit also employs the capacitors Ci and Co which are the decoupling capacitors used to provide AC coupling between the amplifier stages. The values of these capacitances are chosen to such that they provide negligible reactance at the frequency of operation. In particular, the value of the input capacitance Ci should be chosen to be equal to the resistance of the input circuit at the lowest frequency such that it results in a -3dB fall at this frequency. In addition, the value of the output capacitor Co is chosen so that it is equal to the circuit resistance at the lowest operating frequency.

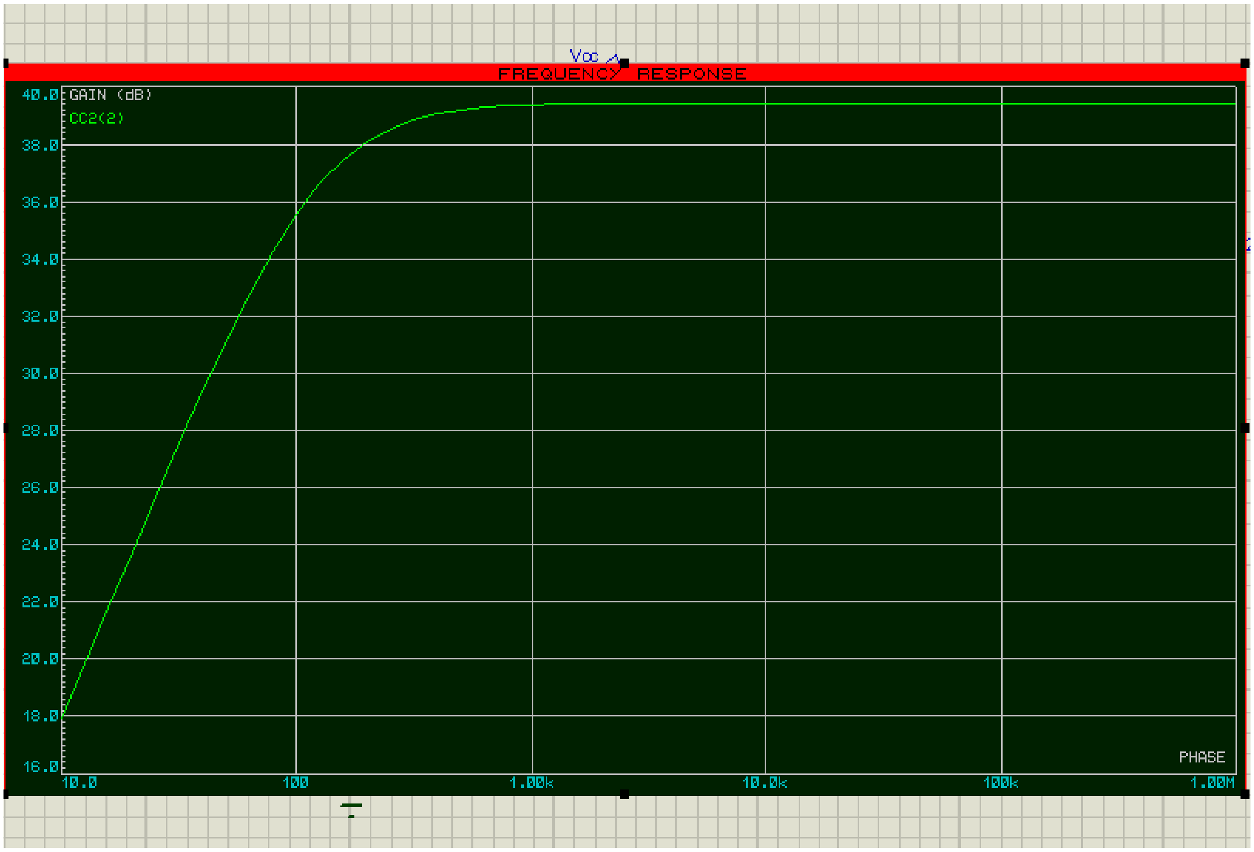
Further the emitter voltage VE is chosen to be 20% of the supply voltage VCC to ensure a good level of DC stability and the current through R1 which is I1 is chosen to be 10 times the required base current. Here it is to be noted that, even I2 will be of almost the same value as the base current IB will be negligible. The emitter bypass capacitor CE when added into the circuit, increases its gain considerably by short-circuiting the emitter resistance RE for high frequency signals, which results in the reduction of the overall transistor load. The value of this CE is chosen such that the capacitor offers a reactance value which is equal to the 1/10thof RE at the lowest operating frequency.

Specifications of BJT BC547B:

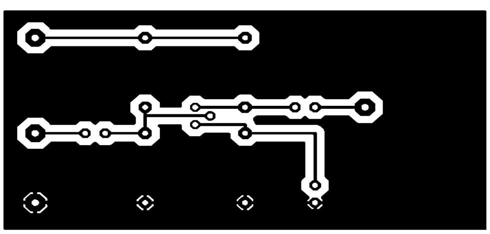
Symbol	MIN	TYP	MAX	UNITS
h_{fe}	240	330	500	-
h_{FE}	200	290	450	-
h_{ie}	-	$4.5*10^3$	-	ohms
h_{re}	$2*10^{-4}$	-	-	-
h_{oe}	30	-	-	u mho

Proteus Output:





Eagle layout:



Data Sheet:

Absolute Maximum Ratings (Ta = 25 °C unless specified otherwise)

DESCRIPTION	SYMBOL	BC546	BC547	BC548	UNITS
Collector Base Voltage	V_{CBO}	80	50	30	V
Collector Emmitter Voltage (V_{BE} = 0V)	V_{CES}	80	50	30	V
Collector Emitter Voltage	V_{CEO}	65	45	30	V
Emitter Base Voltage	V_{EBO}	6	6	5	V
Collector Current (DC)	I_C		100		mA
Collector Current - Peak	I_{CM}		200		mA
Emitter Current - Peak	I_{EM}		200		mA
Base Current - Peak	I_{BM}		200		mA
Total power dissipation up to T_{amb} = 25 °C	P_{tot}		500		mW
Storge Temperature	Tstg		-55 to +150		°C
Junction Temperature	Tj		150		°C

Thermal Resistance

From junction to ambient	$R_{th(j-a)}$		250		°C/W

Electrical Characteristics (Ta=25 °C unless otherwise specified)

DESCRIPTION	SYMBOL	TEST CONDITION	MIN	TYP	MAX	UNITS
DYNAMIC CHARACTERISTICS						
Transition Frequency	f_T	I_C = 10mA, V_{CE} = 5V, f = 100MHz		300		MHz
Collector output Capacitance	C_{cbo}	V_{CB} = 10V, f = 1MHz		1.7	4.5	pF
Emitter input Capacitance	C_{ib}	V_{EB} = 0.5V, f = 1MHz		9		pF
Noise Figure	NF	VCE = 5V, I_C = 0.2mA R_S= 2k ohm, f = 1KHz, B= 200Hz		2	10	dB
Small Signal Current Gain	h_{fe}	V_{CE} = 5V, I_C = 2mA, f= 1kHz				
		BC546A/BC547A/BC548A		220		
		BC546B/BC547B/BC548B		330		
		BC546C/BC547C/BC548C		600		
Input Impedance	h_{ie}	V_{CE} = 5V, I_C = 2mA, f= 1kHz				k ohm
		BC546A/BC547A/BC548A	1.6	2.7	4.5	
		BC546B/BC547B/BC548B	3.2	4.5	8.5	
		BC546C/BC547C/BC548C	6	8.7	15	
Voltage Feedback	h_{re}	V_{CE} = 5V, I_C = 2mA, f= 1kHz				x10
		BC546A/BC547A/BC548A		1.5		
		BC546B/BC547B/BC548B		2		
		BC546C/BC547C/BC548C		3		
DYNAMIC CHARACTERISTICS						
Output Admittance	h_{oe}	V_{CE} = 5V, I_C = 2mA, f= 1kHz				u MHO
		BC546A/BC547A/BC548A		18	30	
		BC546B/BC547B/BC548B		30	60	
		BC546C/BC547C/BC548C		60	110	

Note (1): I_B is value for which I_C = 11mA @ V_{CE} = 10V.

Electrical Characteristics (Ta=25 °C unless otherwise specified)

DESCRIPTION	SYMBOL	TEST CONDITION	MIN	TYP	MAX	UNITS
Collector Emitter Voltage	V_{CEO}	I_C = 1mA, I_B = 0				V
BC546/BC546A/BC546B/BC546C			65			
BC547/BC547A/BC547B/BC547C			45			
BC548/BC548A/BC548B/BC548C			30			
Collector Base Voltage	V_{CBO}	I_C = 100uA, I_E = 0				V
BC546/BC546A/BC546B/BC546C			80			
BC547/BC547A/BC547B/BC547C			50			
BC548/BC548A/BC548B/BC548C			30			
Emitter Base Voltage	V_{EBO}	I_E = 10uA, I_C = 0				V
BC546/BC546A/BC546B/BC546C			6			
BC547/BC547A/BC547B/BC547C			6			
BC548/BC548A/BC548B/BC548C			5			
Collector Cut off Current	I_{CBO}	V_{CB} = 30V, I_E = 0			15	nA
		V_{CB} = 30V, I_E = 0, Tj = 150°C			5	uA
Collector Cut off Current	I_{CES}					
BC546/BC546A/BC546B/BC546C		V_{CE} = 80V		0.2	15	nA
BC547/BC547A/BC547B/BC547C		V_{CE} = 50V		0.2	15	nA
BC548/BC548A/BC548B/BC548C		V_{CE} = 30V		0.2	15	nA
BC546/BC546A/BC546B/BC546C		V_{CE} = 80V, Tj = 125°C			4	uA
BC547/BC547A/BC547B/BC547C		V_{CE} = 50V, Tj = 125°C			4	uA
BC548/BC548A/BC548B/BC548C		V_{CE} = 30V, Tj = 125°C			4	uA
Base Emitter On Voltage	$V_{BE(on)}$	I_C = 2mA, V_{CE} = 5V	0.55	0.66	0.7	V
		I_C = 10mA, V_{CE} = 5V			0.77	
Collector Emitter Saturation Voltage	$V_{CE(Sat)}$	I_C = 10mA, I_B = 0.5mA		0.09	0.25	V
		I_C = 10mA, I_B = 5mA		0.2	0.60	
		I_C = 100mA, I_B = see note (1)		0.3	0.60	
Base Emitter Saturation Voltage	$V_{BE(Sat)}$	I_C = 10mA, I_B = 0.5mA		0.7		V
		I_C = 100mA, I_B = 5mA		0.9		
DC Current Gain	h_{FE}	VCE = 5V, I_C = 10uA				
		BC546A/BC547A/BC548A		90		
		BC546B/BC547B/BC548B		150		
		BC546C/BC547C/BC548C		270		
		VCE = 5V, I_C = 2mA				
		BC546	110		450	
		BC547/BC548	110		800	
		BC546A/BC547A/BC548A	110	180	220	
		BC546B/BC547B/BC548B	200	290	450	
		BC546C/BC547C/BC548C	420	520	800	
		VCE = 5V, I_C = 100mA				
		BC546A/BC547A/BC548A		120		
		BC546B/BC547B/BC548B		200		
		BC546C/BC547C/BC548C		400		

Note (1): I_B is value for which I_C = 11mA @ V_{CE} = 10V.