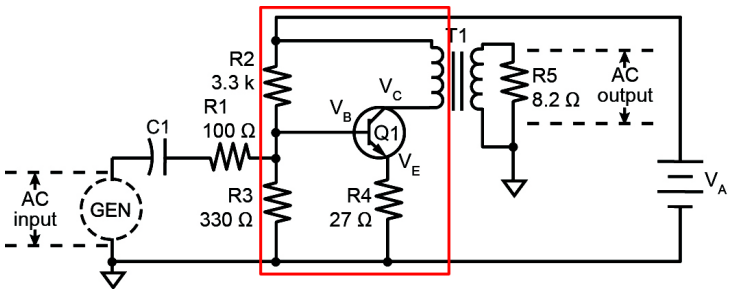
Exercise 1: DC Operation

EXERCISE OBJECTIVE

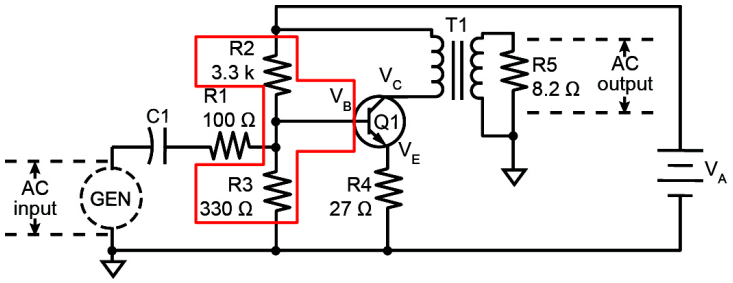
When you have completed this exercise, you will be able to measure dc operating voltages and currents by using a typical single-ended power amplifier circuit. You will verify your results with a multimeter.

DISCUSSION

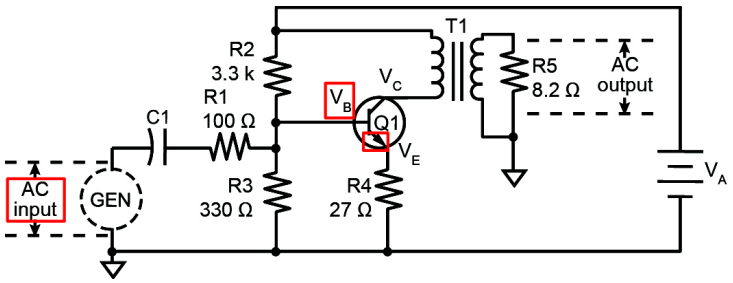
In the single-ended power amplifier circuit shown, Q1 is an NPN transistor connected in a common-emitter configuration.



Resistors R2 and R3 function as a voltage divider to set the Q1 base voltage (V_B).

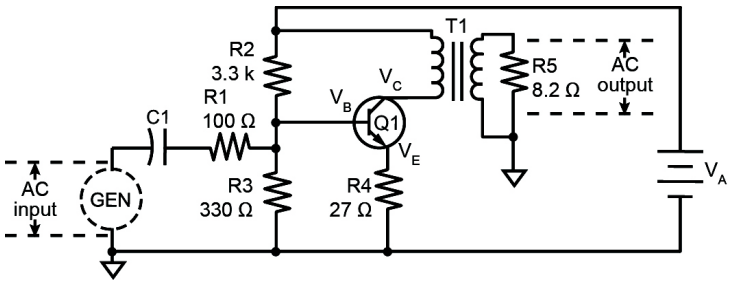


The base voltage (V_B) is set high enough to always forward bias the Q1 base-emitter junction for the magnitude range of the ac input signal.

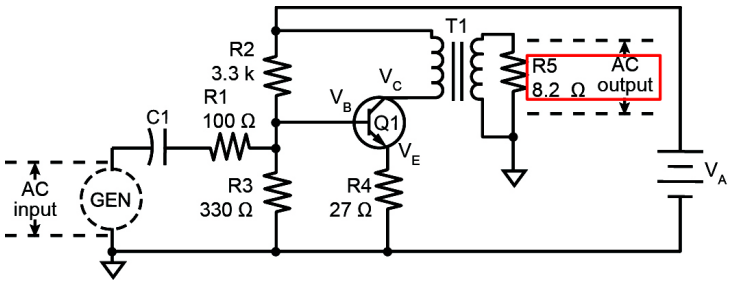


Because the base-emitter junction is always forward biased (Q1 is never cut off), the Q1 collector current flows

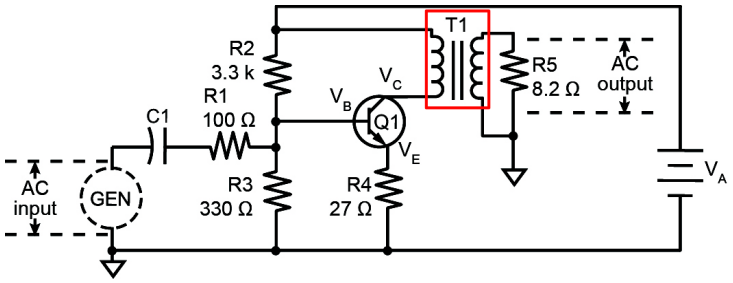
a. only during the positive (180º) phase of the input signal.
b. during the positive and negative phases (360º) of the input signal.



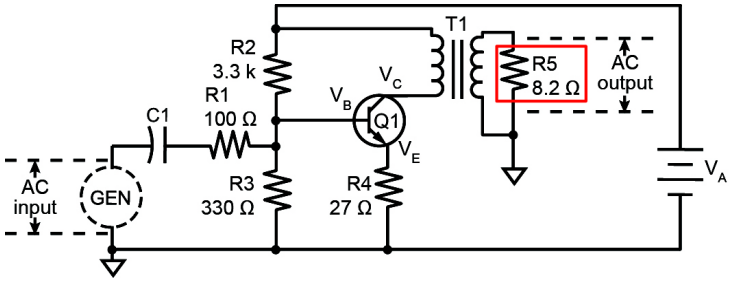
The ac output load resistor (R5) is transformer-coupled to the collector of Q1.



Transformer T1 (turns ratio is 6.13:1) matches the low impedance of R5 (8.2 Ω) to the high impedance output of the Q1 collector circuit.

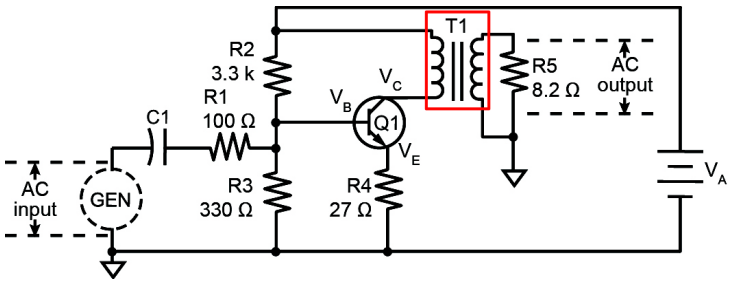


When there is no ac input signal, no current flows in the load resistor (R5) because only ac signals can be coupled through a transformer.



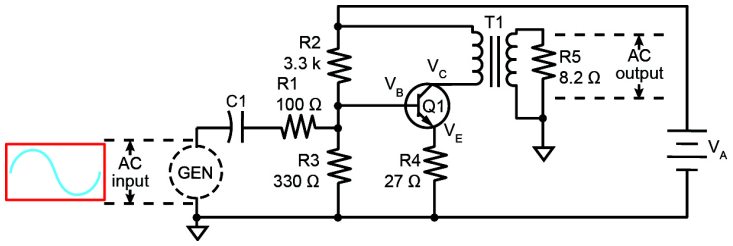
The purpose of the transformer (T1) is to

a. match the low impedance of the load to the high impedance output of the Q1 collector circuit.
b. prevent current in the load when there is no ac input signal.

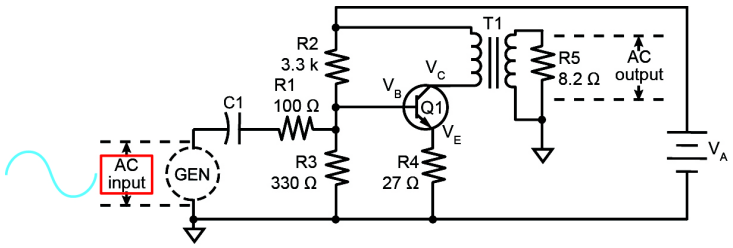


The ac input sine wave used in the PROCEDURE has low distortion and is centered around 0.

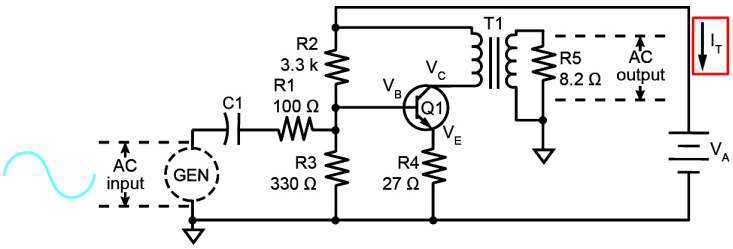
The average ac current value is said to be 0.



The peak voltage of the ac input signal is maintained below the point at which the negative peak would cause the transistor (Q1) to cut off.

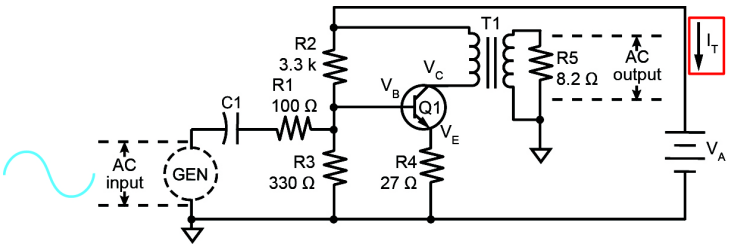


The total circuit current (I_T) is the same with or without an ac input signal. As a result, the amplifier operation is class A; there is no amplitude distortion of the ac output signal.

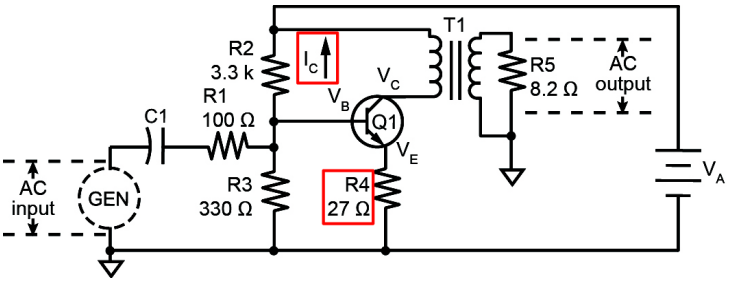


How does an ac input signal affect the total circuit current of the single-ended power amplifier?

a. increases the current
b. decreases the current
c. does not affect the current

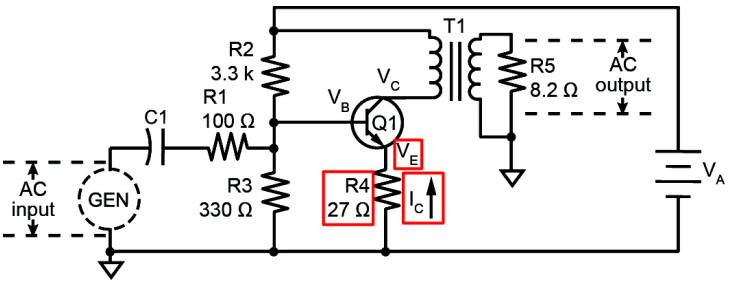


The value of the emitter resistor (R4) is small in order to provide a large collector current (I_C); the collector current is essentially equal to the emitter current (I_E).

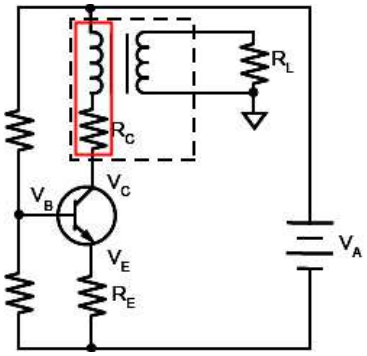


Calculate emitter current (I_E) by using Ohm's law.

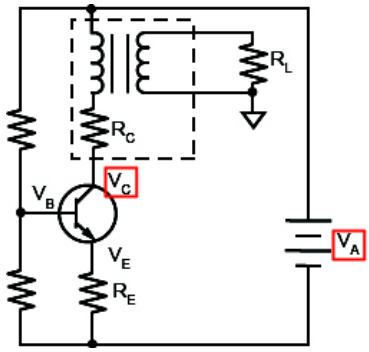
$$I_E = \frac{V_E}{R4}$$



The dc resistance of the transformer primary coil (R_C), which is very low, is the collector resistance.

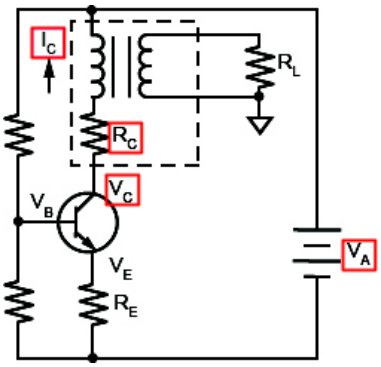


Collector voltage (V_C) almost equals the dc supply voltage (V_A) because of the very low resistance (about 18.4 Ω) of the transformer primary coil.



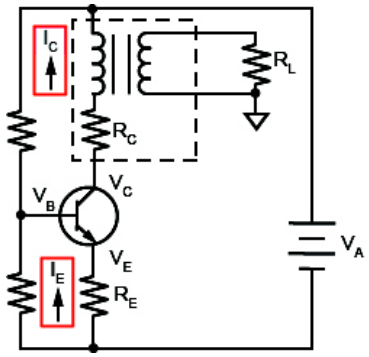
Use Ohm's law to calculate the collector current (I_C).

$$I_C = \frac{V_A - V_C}{R_C}$$



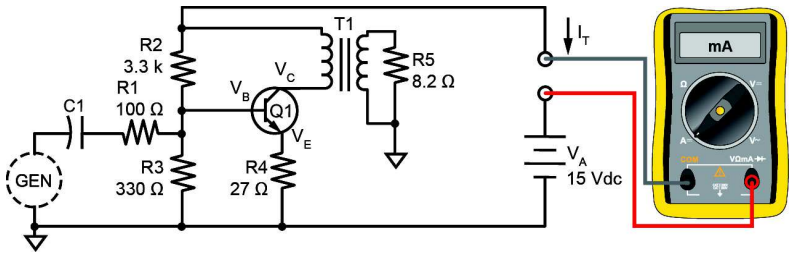
The Q1 collector current (I_C) is about

a. two times the emitter current because of the difference in the collector and emitter resistances.
b. half the emitter current because of the differences in the collector and emitter resistances.
c. the same as the emitter current.

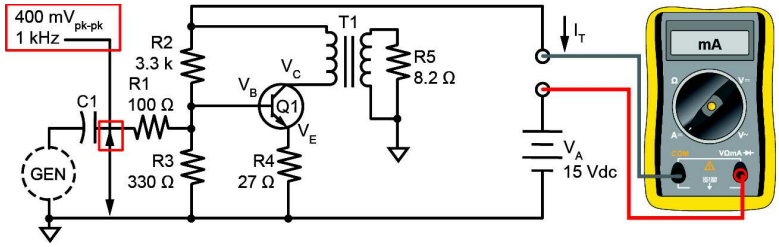


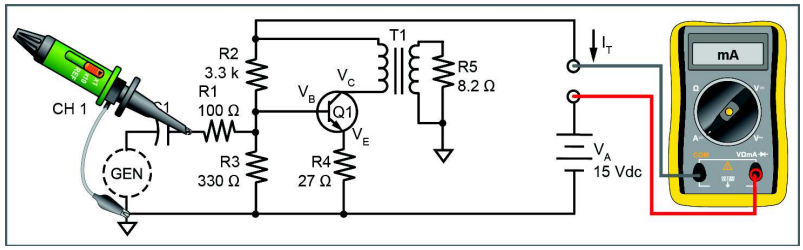
PROCEDURE

☐ 1. Locate the SINGLE-ENDED POWER AMPLIFIER circuit block on the TRANSISTOR POWER AMPLIFIERS circuit board, and connect the circuit shown.



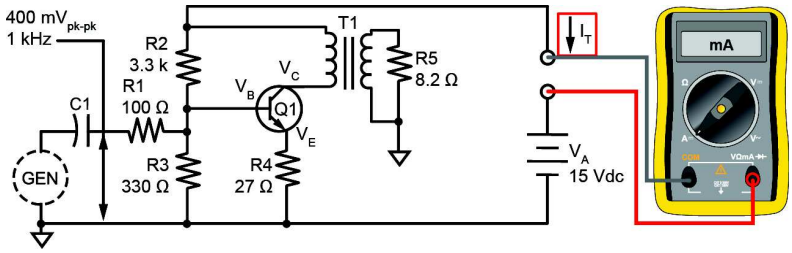
☐ 2. While observing the signal on channel 1 of the oscilloscope, adjust the sine wave generator for a 400 mV_{pk-pk}, 1 kHz ac input at the junction of C1 and R1.





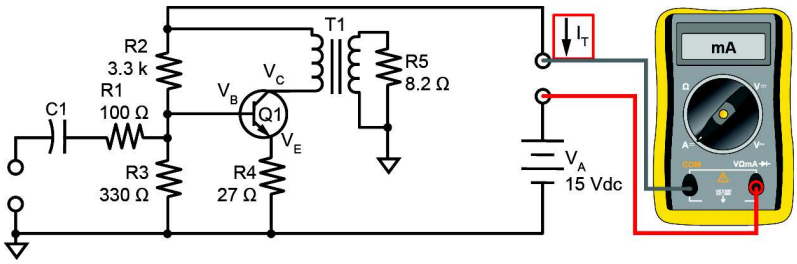
☐ 3. Measure the total signal dc circuit current ($I_{T(signal)}$) with an ac signal applied.

$I_{T(signal)}$ =_____ mA (*Recall Value 1*)



4. Disconnect the sine wave generator. Measure the total no-signal dc circuit current ($I_{T(no\text{-}signal)}$).

$I_{T(no\text{-}signal)}$ =_____ mA (*Recall Value 2*)



5. Is total dc current affected by the ac signal?

$I_{T\ (signal)}$ =_____ mA (Step 3, *Recall Value 1*)

$I_{T\ (no\text{-}signal)}$ =_____ mA (Step 4, *Recall Value 2*)

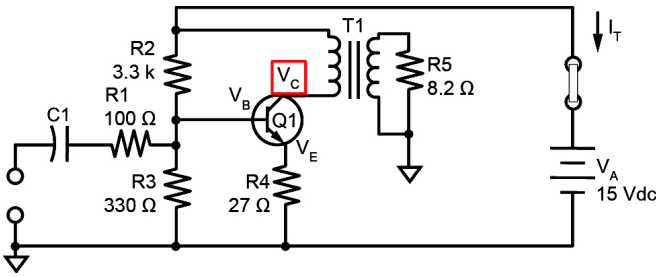
a. yes
b. no

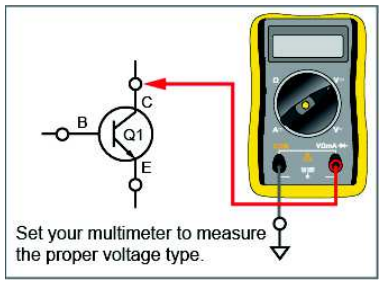
6. When the total dc current is not affected by the ac signal, does the single-ended power amplifier operate as a class A amplifier?

a. yes
b. no

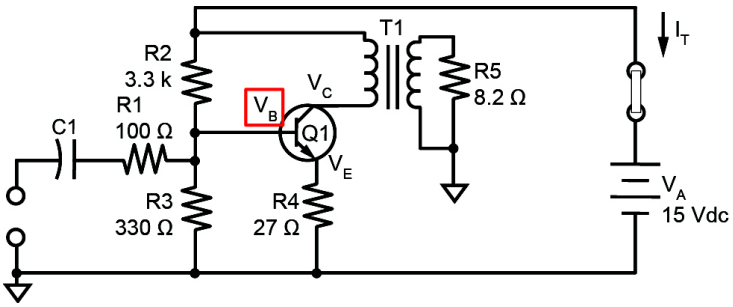
7. Replace the ammeter with a two-post connector. Measure the dc voltages below at the transistor (Q1).

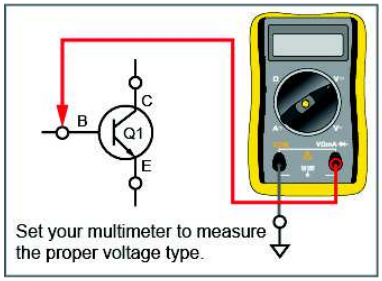
V_C =_____ Vdc (*Recall Value 3*)



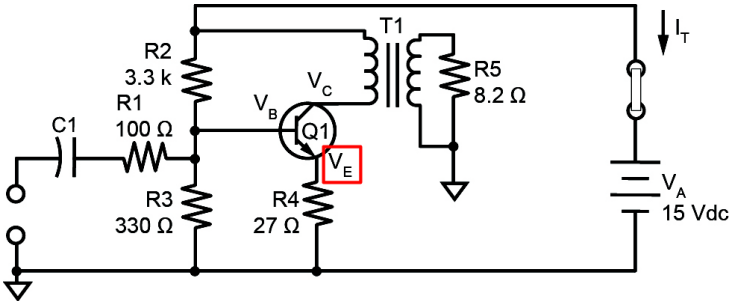


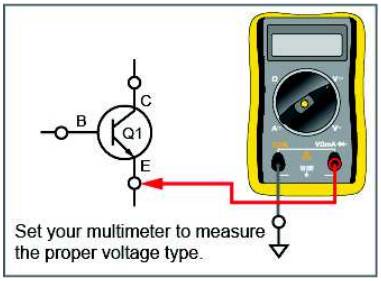
V_B =_____ Vdc (*Recall Value 4*)





V_E =_____ Vdc (*Recall Value 5*)





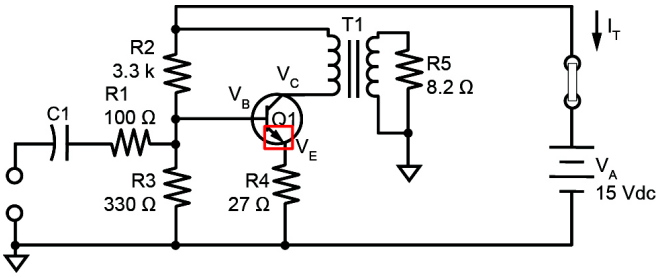
☐ 8. Is the base-emitter junction forward or reverse biased?

V_C = _____ Vdc (Step 7, *Recall Value 3*)

V_B = _____ Vdc (Step 7, *Recall Value 4*)

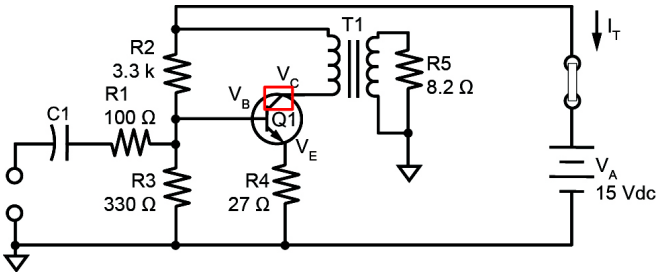
V_E = _____ Vdc (Step 7, *Recall Value 5*)

a. forward biased
b. reverse biased



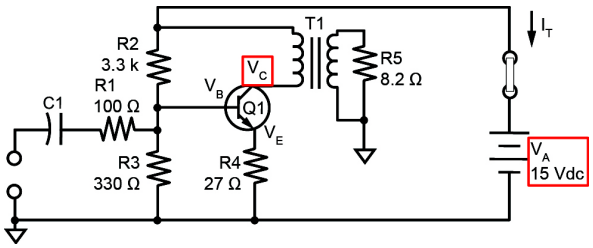
9. Is the base-collector junction forward biased or reverse biased?

   a. forward biased
   b. reverse biased



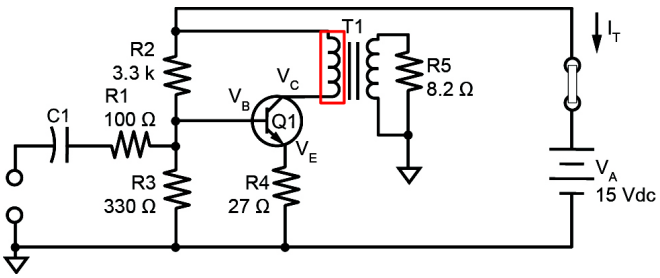
10. For a voltage amplifier, V_C is usually about half the supply voltage (15 Vdc). For this power amplifier, is V_C (_____ Vdc [Step 7, *Recall Value 3*]) half of V_A?

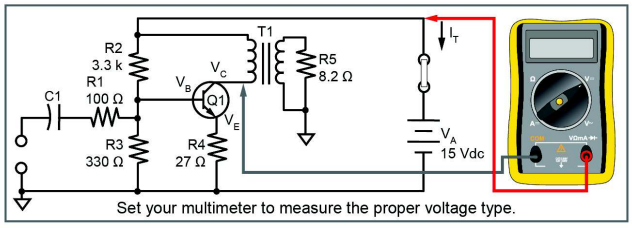
    a. yes
    b. no



11. Measure the voltage drop of the transformer (T1) primary coil, which is measured between V_A and V_C.

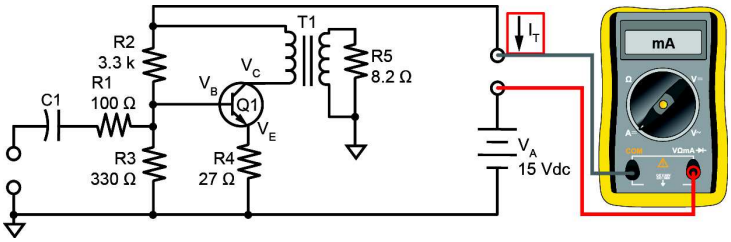
$V_{(T1)\ primary\ coil}$ =_____ Vdc (*Recall Value 6*)





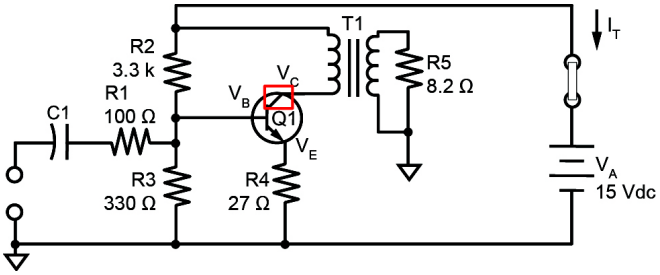
☐ 12. V_C (_____ Vdc [Step 7, *Recall Value 3*]) is slightly less than V_A (15 Vdc) because the

a. dc resistance of the transformer primary coil is very low.
b. dc current through the primary coil is 0.



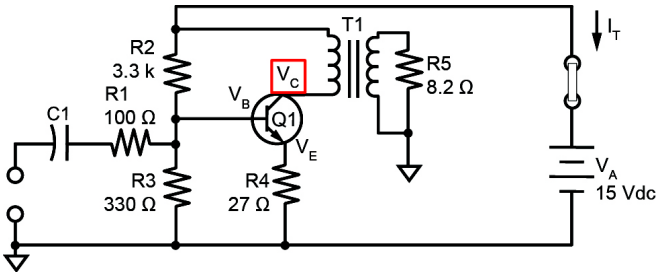
☐ 13. Place circuit modification (CM) 4 in the ON position to simulate an open circuit in the collector of the transistor. What should V_C equal now?

a. 0 Vdc
b. V_A (15 Vdc)



☐ 14. Measure V_C with an open circuit (CM 4 activated) in the Q1 collector.

V_C =_____ Vdc (*Recall Value 7*)



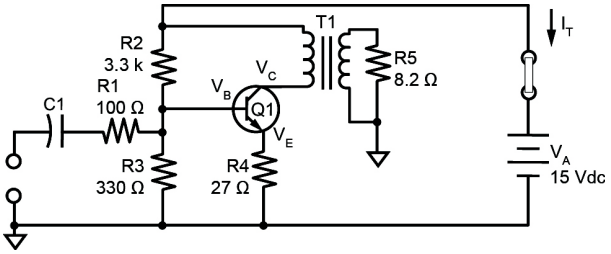
☐ 15. Make sure all CMs are cleared (turned off) before proceeding to the next section.

CONCLUSION

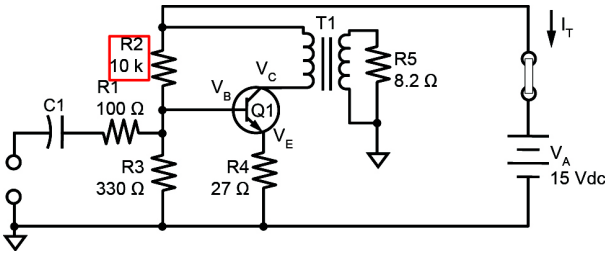
- The single-ended power amplifier base voltage is set high enough by the voltage divider circuit to forward bias the base-emitter junction for all values of the ac input signal.
- An output transformer matches the low impedance output load to the high impedance of the transistor collector circuit.
- The total dc current is unaffected by an ac input signal; therefore, the single-ended power amplifier operates as a class A amplifier, which has no amplitude distortion.
- Because of the low resistance of the transformer primary coil, the collector voltage (V_C) almost equals the supply voltage (V_A).
- The emitter resistor, which maintains bias stability, has a low value to cause high emitter and collector currents.

REVIEW QUESTIONS

1. Locate the SINGLE-ENDED POWER AMPLIFIER circuit block, and connect the circuit shown.



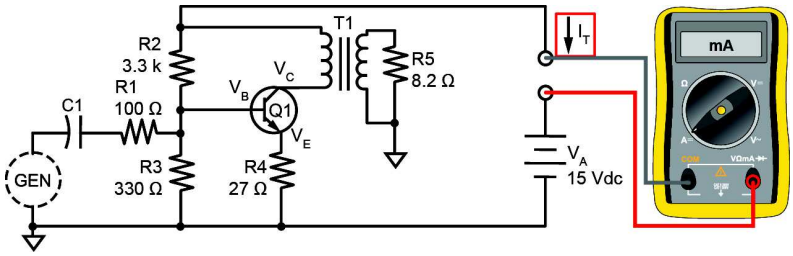
Place CM switch 1 in the ON position to increase the value of voltage divider resistor R2 from 3.3 kΩ to 10 kΩ. During the procedure, you measured base voltage to be about 1.4 Vdc when CM 1 was not activated. Take voltage readings around Q1.



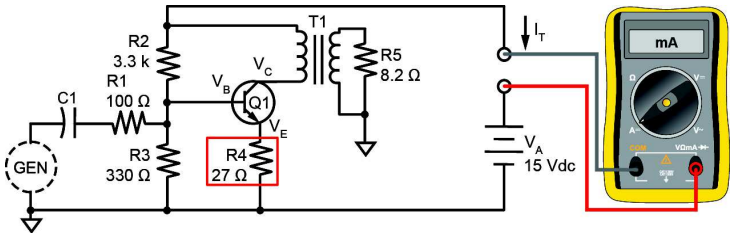
With R2 changed to 10 kΩ, the emitter current

a. increases.
b. is 0 mA.
c. decreases to about half the original value.
d. remains the same.

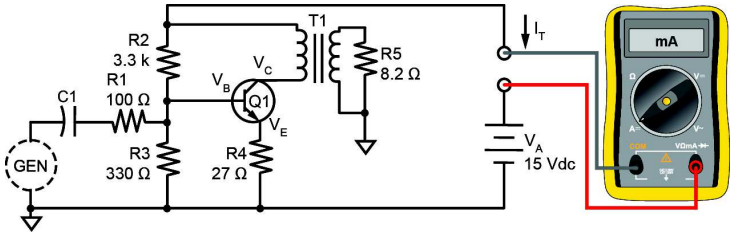
2. For the circuit current to remain constant with or without an ac input signal, transistor Q1 must be biased so that the
   a. base-collector junction is always forward biased.
   b. base-collector junction is always reverse biased.
   c. base-emitter junction is always forward biased.
   d. base-emitter junction is always reverse biased.



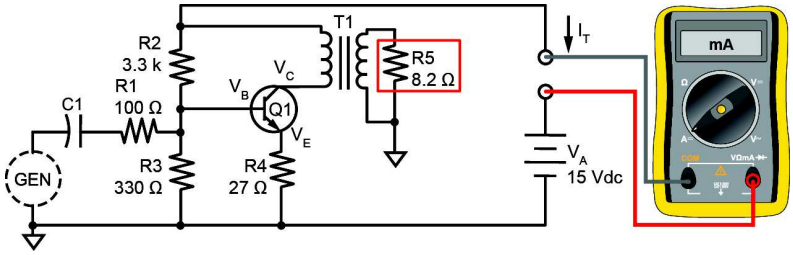
3. The value of the emitter resistor (R4) is purposely made low (27 Ω) so that the
   a. collector current is high.
   b. base current is low.
   c. base voltage is high.
   d. collector impedance is low.



4. The single-ended power amplifier operates as a class
   a. A amplifier.
   b. B amplifier.
   c. C amplifier.
   d. AB amplifier.



5. The load resistor (R5) is transformer-coupled to the Q1 collector circuit to
   a. block unwanted ac noise.
   b. increase the voltage gain.
   c. lower the total no-signal dc circuit current.
   d. match the load and transistor output (collector) impedances.



Note: Make sure all CMs are cleared (turned off) before proceeding to the next section.