电子科技大学
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Communication Circuits Design

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Lecture 3.2: Amplitude Modulation (AM) – Part 2

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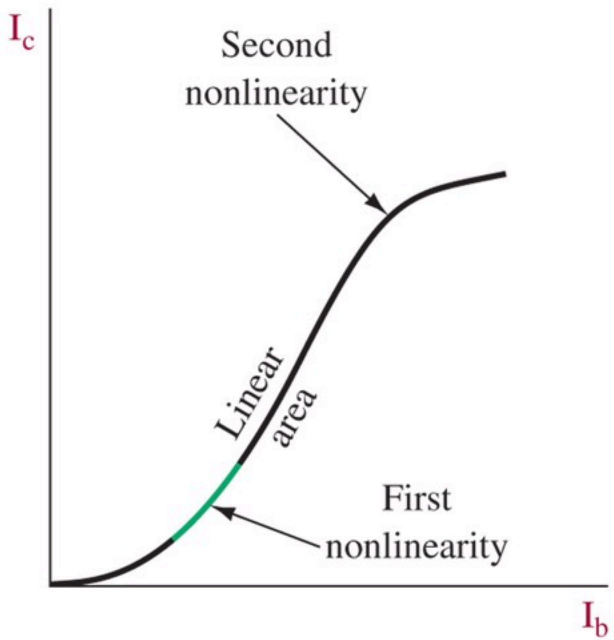
Circuits for AM Generation

- Amplitude modulation is generated by combining carrier and intelligence frequencies through a nonlinear device.
- Diodes have nonlinear areas, but they are not often used because, being passive devices, they offer no gain.
- Transistors offer nonlinear operation (if properly biased) and provide amplification, thus making them ideal for this application.

Transistor Nonlinear areas

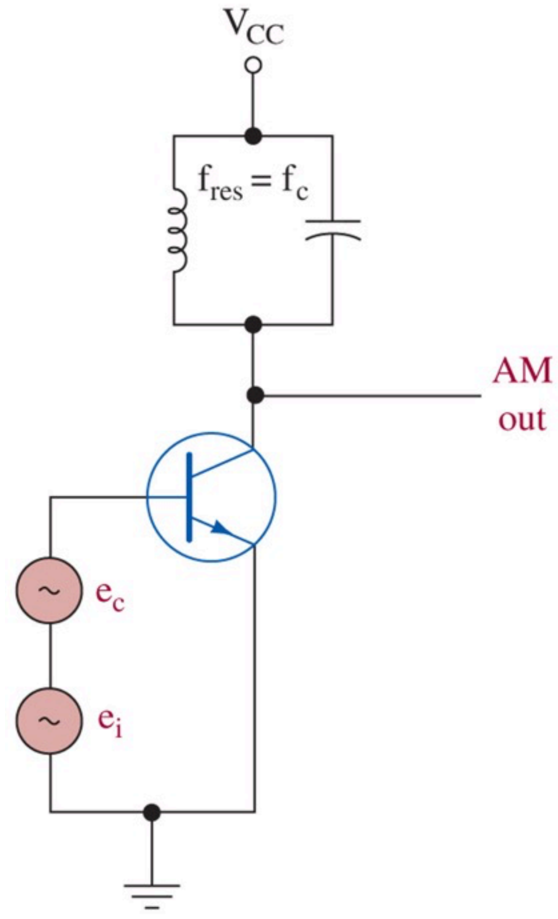
- Figure shows an input/output relationship for a typical bipolar junction transistor (BJT). Notice that at both low and high values of current, nonlinear areas exist.

- Between these two extremes is the linear area that should be used for normal amplification. One of the nonlinear areas must be used to generate A.M.



Transistor Modulator (1)

- Figure shows a very simple transistor modulator.
- It operates with no base bias and thus depends on the positive peaks of e_c and e_i to bias it into the first nonlinear area shown in Figure 10(a).
- Proper adjustment of the levels of e_c and e_i is necessary for good operation.
- Their levels must be low to stay in the first nonlinear area, and the intelligence power must be one-half the carrier power (or less) for 100 percent modulation (or less).



Transistor Modulator (2)

- In the collector a parallel resonant circuit, tuned to the carrier frequency, is used to tune into the three desired frequencies—the upper and lower sidebands and the carrier.

- The resonant circuit presents a high impedance to the carrier (and any other close frequencies such as the sidebands) and thus allows a high output to those components.

- But it presents very low impedance to all other frequencies effectively shorts them out.

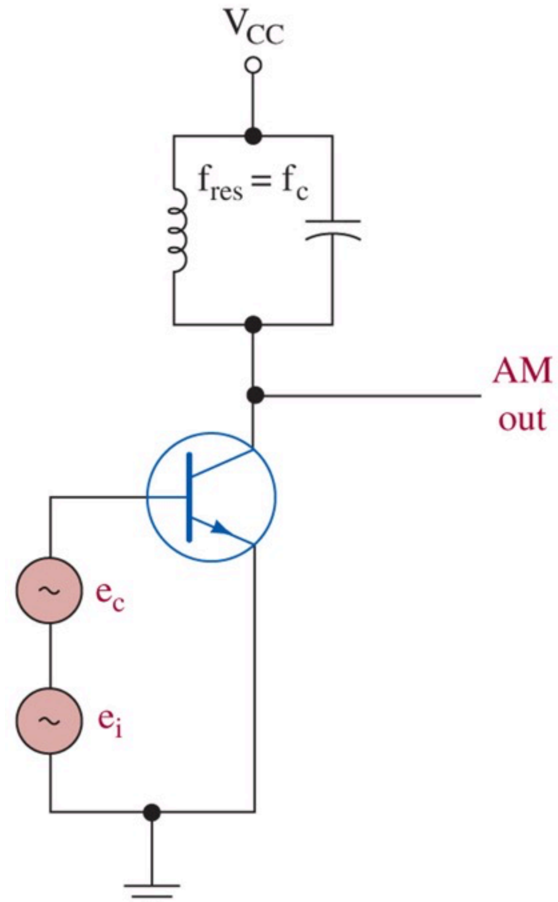
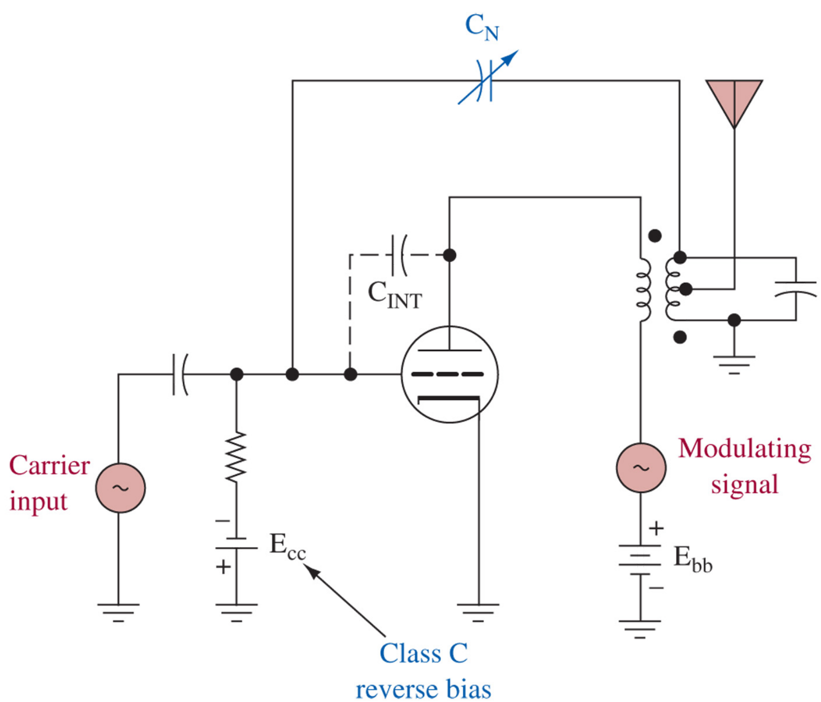


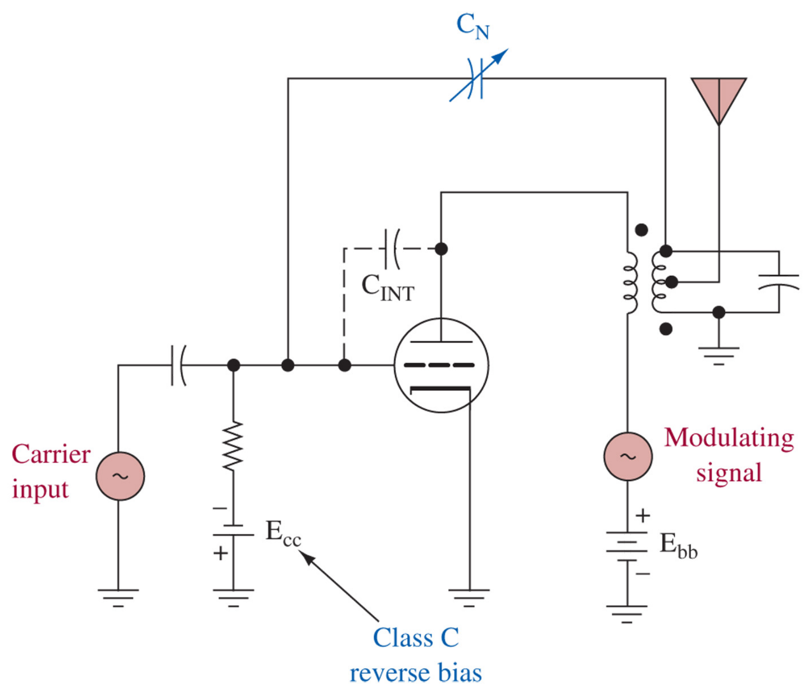
Plate-Modulated Amplifier

- Another common designator for modulators involves whether or not the intelligence is injected at the last possible place or not.
- The plate-modulated circuit shown in Figure below has the intelligence added at the last possible point before the transmitting antenna and is termed a high-level modulation scheme.



Neutralization

- The variable capacitor, C_N, connected from the plate tank circuit back to the grid. It is termed the neutralizing capacitor.
- It provides a path for the return of a signal that is 180° out of phase with the signal returned from plate to grid via the internal interelectrode capacitance (C_{INT}) of the tube .
- C_N is adjusted to cancel the internally fed-back signal to reduce the tendency of self-oscillation.
- The transformer in the plate is made to introduce a 180° phase shift by appropriate wiring.

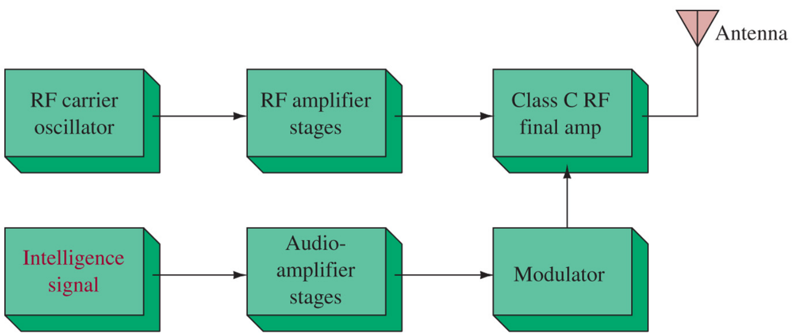


High- & Low-Level Modulation (1)

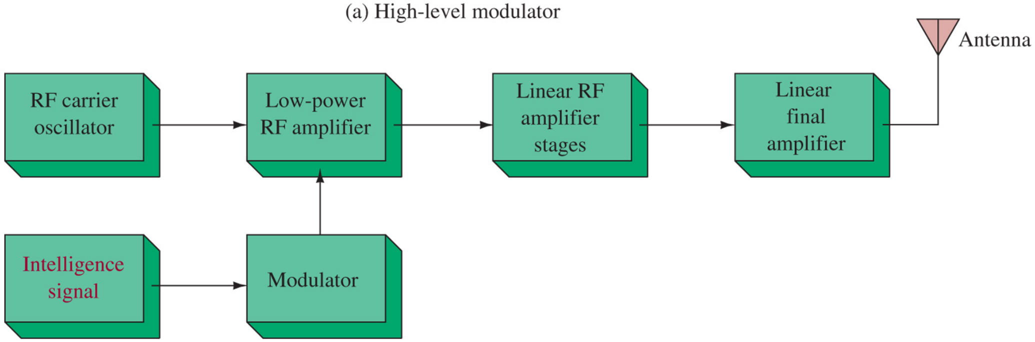
- If the intelligence is added at the last possible point before the transmitting antenna, it is termed a high-level modulation scheme.
- If the intelligence was injected at any previous point, such as at a base, emitter, grid, or cathode, or even at a previous stage, it would be termed low-level modulation.
- The designer's choice between high- and low-level systems is made largely on the basis of the required power output.
- For high-power applications such as standard radio broadcasting, where outputs are measured in terms of kilowatts instead of watts, high-level modulation is the most economical approach.

High- & Low-Level Modulation (2)

- Block diagrams for typical high- and low-level modulator systems are shown *in* Figure below.
- Note that in the high-level modulation system the majority of power amplification takes place in the highly efficient class C amplifier.
- The low-level modulation scheme has its power amplification take place in the much less efficient linear final amplifier.



(a) High-level modulator



(b) Low-level modulator

Power Amplifiers for Transmitter (1)

- Vacuum tubes are still the best choice for many high-frequency, high-power transmitter outputs.
- Recall that class C bias (device conduction for less than 118^{o}) allows for the highest possible efficiency.
- It realistically provides 70 to 80 percent efficiency as compared to about 50 to 60 percent for the next best configuration, a class B (linear) amplifier.
- However, class C amplification cannot be used for reproduction of the complete AM signal, and hence large amounts of intelligence power must be injected at the final output to provide a high-percentage modulation.

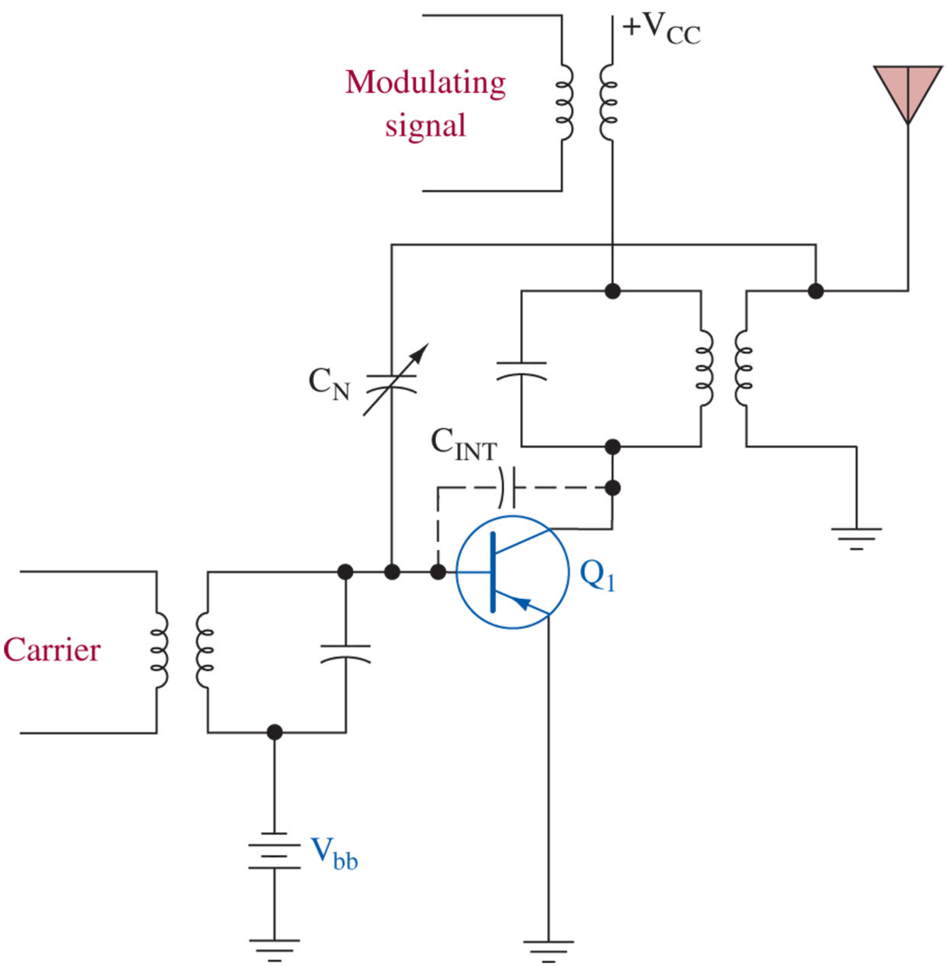
Power Amplifiers for Transmitter (2)

- The modulation process is accomplished in a nonlinear device, but all circuitry that follows must be linear.
- This is required In provide reproduction of the AM signal without distortion.
- The class C amplifier is not linear but can reproduce (and amplify) the single frequency carrier. However, it would distort the carrier and sidebands combination of the AM signal.
- This is due to their changing amplitude that would be distorted by the flywheel effect in the class C tank circuit.

Collector Modulator (1)

- Figure shows a transistorized class C, high-level modulation scheme.

- Class C operation provides an abrupt nonlinearity when the device switches on and off, which allows for the generation of the sum and difference frequencies.



Collector Modulator (2)

- This is in contrast to the use of the gradual nonlinearities offered by a transistor at high and low levels of class A *bias*.
- Generally, the operating point is established to allow half the maximum ac output voltage to be supplied at the collector when the intelligence signal is zero.
- The tank circuit in Q_1's collector is tuned to resonate at f_c, and thus the full carrier sine wave is reconstructed there by the flywheel effect at the extremely high efficiency afforded by class C operation.

Collector Modulator (3)

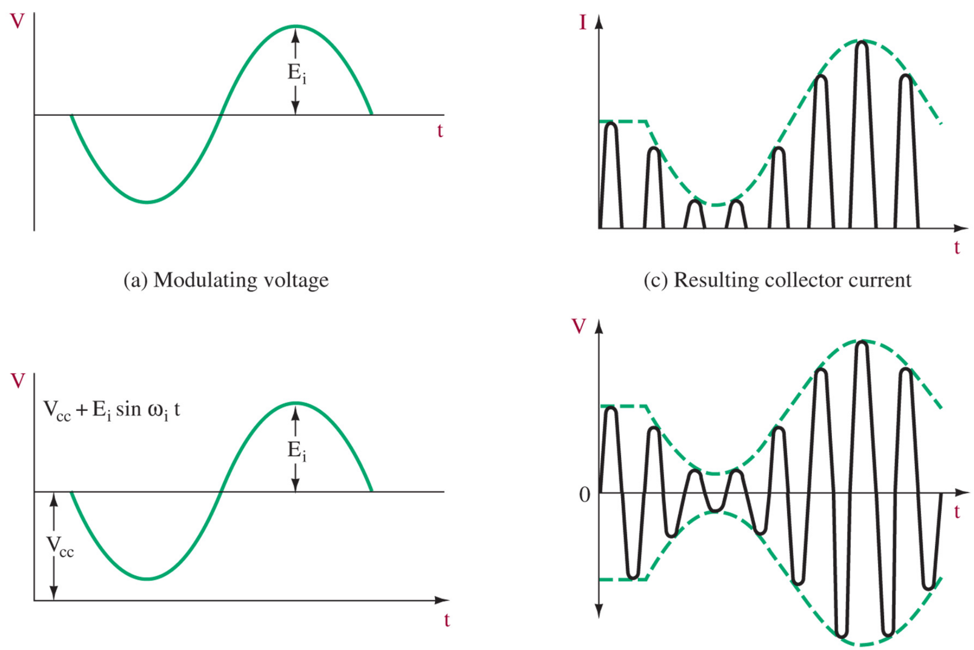
- The intelligence (modulating) signal for the collector modulator of Figure is added directly in series with the collector supply voltage.
- The net effect of the intelligence signal is to vary the energy available to the tank circuit each time Q_1 conducts on the positive peaks of carrier input.
- This causes the output to reach a maximum value when the intelligence is at its peak positive value and a minimum value when the intelligence is at its peak negative value.
- Since the circuit is biased to provide one-half of the maximum possible carrier output when the intelligence is zero, theoretically an intelligence signal level exists where the carrier will swing between twice its static value and zero.

Collector Modulator (4)

- This is a fully modulated (100 percent modulation) AM waveform.
- In practice, however, the collector modulator cannot achieve 100 percent modulation because the transistor's knee in its characteristic curve changes at the intelligence frequency rate.
- This limits the region over which the collector voltage can vary, and slight collector modulation of the preceding stage is necessary to allow the high modulation indexes that are usually desirable.
- This is sometimes not a necessary measure in the tube-type high-level modulators.

Collector Modulator Waveform (1)

- Figure (a) shows an intelligence signal for a collector modulator.
- Figure (b) shows its effect on the collector supply voltage.



(a) Modulating voltage

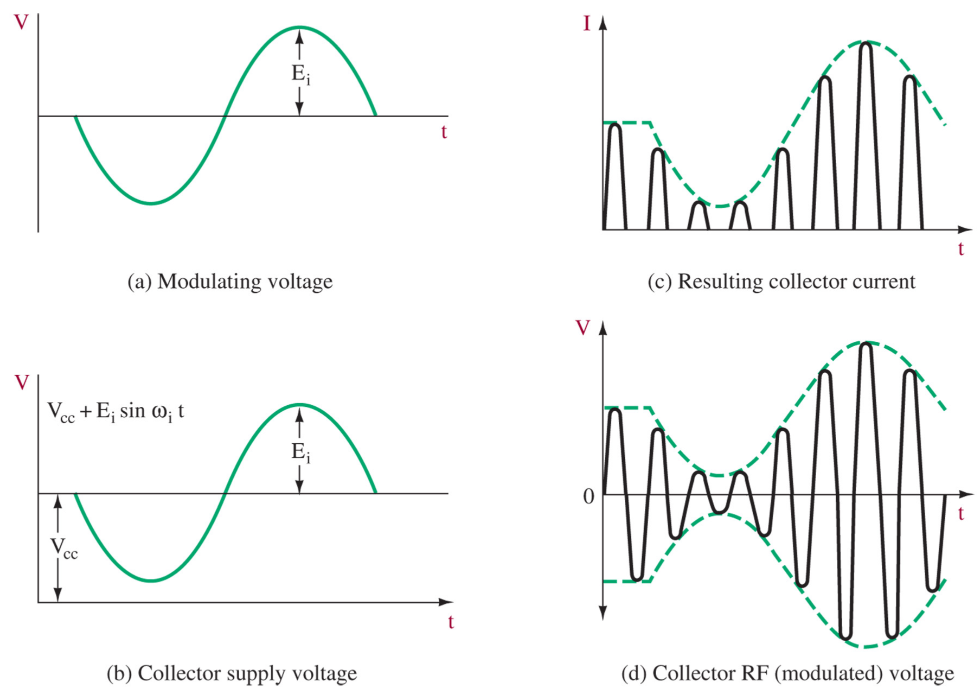
(c) Resulting collector current

(b) Collector supply voltage

(d) Collector RF (modulated) voltage

Collector Modulator Waveform (2)

- In Figure (c), the resulting collector current variations that are in step with the available supply voltages are shown.
- Figure (d) shows the collector voltage produced by the flywheel effect of the tank circuit as a result of the varying current peaks that am flowing through the tank.



(a) Modulating voltage

(c) Resulting collector current

(b) Collector supply voltage

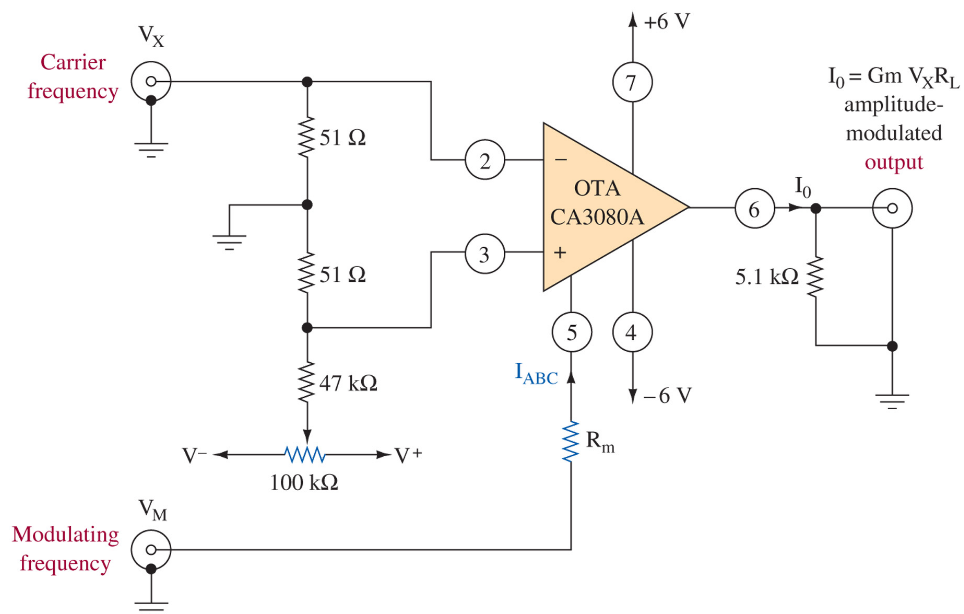
(d) Collector RF (modulated) voltage

Linear-Integrated-Circuit (LIC) Modulators

- The process of generating high-quality AM signals economically is greatly simplified by the availability of low-cost specialty linear integrated circuits (LICs),
- This is especially true For low-power systems, where low-level modulation schemes are attractive.
- For example. the RCA CA3080 operational transconductance amplifier (OTA) can be used to provide AM with an absolute minimum of design considerations.
- The OTA is similar to conventional operational amplifiers inasmuch as they employ *the* usual differential input terminals, but its output is best described in terms of the output current, rather than voltage, that it can supply,
- In addition, it contains an extra control terminal that enhances flexibility for use in a variety of applications, including AM generation.

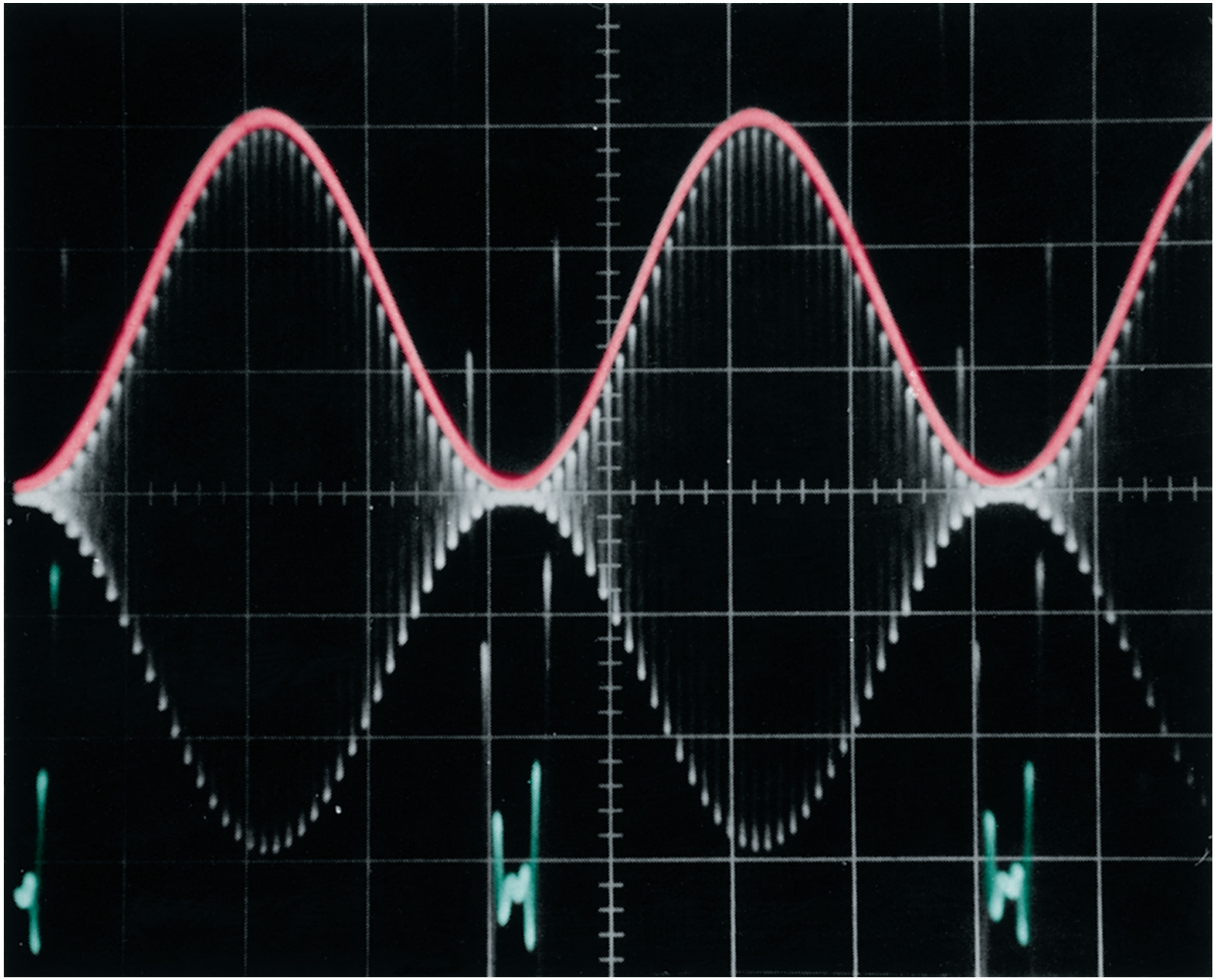
AM Circuit using the OTA

- Figure shows the CA3080 connected as an amplitude modulator.
- The gain of the OTA to the input carrier signal is controlled by variation of the amplifier-bias current at pin 5 (I_{ABC}) because the OTA transconductance (and hence gain) is directly proportional to this current.
- The level of the unmodulated carrier output is determined by the quiescent I_{ABC} current, which is set by the value of The R_m.
- The 100kΩ potentiometer is adjusted to set the output symmetrically about zero, thus nulling the effect of amplifier input offset voltage.



(a) Amplitude modulator circuit using the OTA

LIC Modulator Waveform



References

- Chapter 2 & 3, Beasley and Miller, Modern Electronic Communication, 9^{th} Edition.