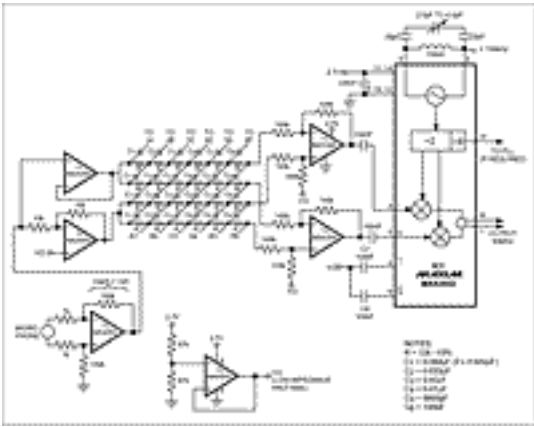


APPLICATION NOTE 1047

## SSB Modulator Draws Only 5mA at 2.7V

*Abstract: Single sideband modulation offers better power efficiency than AM and uses less spectrum. This design uses op amps and RC components to produce the needed phase shift. The MAX2452 forms the I/Q modulator. Undesired sideband and carrier suppression levels are -35dBc.*

Single-sideband modulation (SSB) is more efficient than full-amplitude modulation in its use of the frequency spectrum and in its generation of output power. Though not used for data transmission, SSB is still popular for voice transmission at HF and low VHF. The circuit shown in **Figure 1** generates SSB signals from 35MHz to 80MHz by combining wideband, low-voltage op amps with an IC that integrates all the necessary functions. All ICs shown are specified for operation at 3V ±10%.



[For Larger Image](#)

Figure 1. This SSB modulator generates the lower sideband of a high-frequency carrier modulated by an applied audio signal.

The traditional method for producing SSB is to modulate a carrier, and then filter the output to remove the unwanted sideband and carrier frequencies. This method is sometimes considered wasteful, because it dumps as much as two-thirds of the generated power into a filter. (However, because filtering is not always performed at the output stage, the system doesn't necessarily waste two-thirds of its transmitted power.)

An alternative method for generating SSB is to use the phasing (algebraic) method. In this approach, two modulators (mixers) produce the desired sideband while suppressing the unwanted carrier and other sideband. Two modulators for this purpose, normally used for in-phase (I) and quadrature (Q) modulation in a QAM signal, are available in IC1. The resulting circuit offers several advantages:

- Low-power, low-cost operation
- Output signal (35MHz to 80MHz) includes the 4m and 6m amateur radio bands
- User can shift from upper- to lower-sideband operation by reversing two pairs of connections (rather than changing a filter)
- No filter required
- One IC provides the required tank oscillator, two modulators, and a summing amplifier

The circuit requires no filter for carrier and sideband-frequency suppression because frequency cancellation is inherent in the modulation process. Suppose, for example (ignoring signal magnitudes), that the carrier signal is  $\sin\omega_c t$  and the modulating signal is  $\sin\omega_M t$ . Modulation (mixing) means multiplying the carrier and modulating

signals, as follows:

$$[\sin\omega_M t] [\sin\omega_C t] = 0.5\cos(\omega_M - \omega_C)t - 0.5\cos(\omega_M + \omega_C)t$$

Adding 90° of phase shift to either quantity produces the cosine:  $\sin(\omega_C + 90^\circ)t = \cos\omega_C t$ , and  $\sin(\omega_M + 90^\circ)t = \cos\omega_M t$ . Shifting each of these inputs ( $\sin\omega_M t$  and  $\sin\omega_C t$ ) by 90° and then multiplying them in a separate modulator results in the following:

$$[\cos\omega_M t] [\cos\omega_C t] = 0.5\cos(\omega_M - \omega_C)t + 0.5\cos(\omega_M + \omega_C)t$$

Note that the lower sideband, which appears as  $\cos(\omega_M - \omega_C)t$  at IC1's output, is the sum of these two modulator outputs. The upper sideband, which appears as  $\cos(\omega_M + \omega_C)t$ , is the difference between the modulator outputs.

The RC phasing network was chosen for simplicity, rather than low component count. Using 5% components, the network produces a response of 300Hz to 3500Hz with <1° of phase-shift error and <0.2dB of magnitude error. IC1's suppression of unwanted carrier and sideband frequencies (-35dB) is about 5dB less than expected when using commercial equipment, but is not unreasonable for output power levels below 5W. This suppression performance depends somewhat on the presence of capacitive terminations (C4 and C5) for the unused modulator inputs active-low I and active-low Q. The output stage (not shown) can be a single-transistor buffer, a class C power amplifier, or whatever the application requires.

For simplicity, the circuit is shown operating with IC1's internal free-running oscillator. This arrangement is insufficiently stable; to compensate for this instability, either provide an external source, or connect the oscillator as part of an external phase-locked loop, as explained in the data sheet for the IC (in this case, the MAX2452). An external source can greatly extend the transmit-frequency range.

The circuit was measured while operating with a 142MHz oscillator frequency and a 71MHz carrier. Its -27dB carrier suppression is 8dB short of the typical suppression specified in the MAX2452 data sheet, but is acceptable for a circuit that drives IC1's I and Q inputs in single-ended mode. (Driving them differentially improves performance.) Sideband suppression was at least -36dB (the test setup's noise floor).

*A related idea appeared in the 6/5/97 issue of EDN.*

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Application Note 1047: <http://www.maxim-ic.com/an1047>

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### Related Parts

MAX2452: [QuickView](#) -- [Full \(PDF\) Data Sheet](#) -- [Free Samples](#)

MAX492: [QuickView](#) -- [Full \(PDF\) Data Sheet](#) -- [Free Samples](#)

MAX494: [QuickView](#) -- [Full \(PDF\) Data Sheet](#) -- [Free Samples](#)

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