LANSDALE
Semiconductor, Inc.

ML13175
ML13176
UHF FM/AM Transmitter

**Legacy Device:** *Motorola MC13175, MC13176*

The ML13175 and ML13176 are one chip FM/AM transmitter subsystems designed for AM/FM communication systems. they include a Colpitts crystal reference oscillator, UHF oscillator, ÷ 8 (ML13175) or ÷ 32 (ML13176) prescaler and phase detector forming a versatile PLL system. Targeted applications are in the 260 to 470MHz band and 902 to 982 MHz band covered by FCC Title 47; Part 15. Other applications include local oscillator sources in UHF and 900 MHz receivers, UHF and 900 MHz video transmitters, RF Local Area Networks (LAN), and high frequency clock drivers. ML13175/76 offer the following features;

- UHF Current Controlled Oscillator
- Uses Easily Available 3rd Overtone or Fundamental Crystals for Reference
- Fewer External Parts Required
- Low Operating Supply Voltage (1.8 to 5.0 Vdc)
- Low Supply Drain Currents
- Power Output Adjustable (Up to + 10 dBm)
- Differential Output for Loop Antenna or Balun Transformer Networks
- Power Down Feature
- ASK Modulated by Switching Output On and Off
- (ML13175) $f_O = 8 \times f_{ref}$, (ML13176) $f_O = 32 \times f_{ref}$
- Operating Temperature Range - T_A = -40° to +85°C
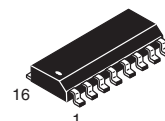
ML13175-5P
PLASTIC PACKAGE
CASE 751B
(SO–16)

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**CROSS REFERENCE/ORDERING INFORMATION**

PACKAGE	MOTOROLA	LANSDALE
SO 16	MC13175D	ML13175-5P
SO 16	MC13176D	ML13176-5P

Note: Lansdale lead free (**Pb**) product, as it becomes available, will be identified by a part number prefix change from **ML** to **MLE**.

PIN CONNECTIONS

Osc 1	1	16	I_{mod}
NC	2	15	Out Gnd
NC	3	14	Out 2
Osc 4	4	13	Out 1
V_{EE}	5	12	V_{CC}
I_{Cont}	6	11	Enable
PD_{out}	7	10	Reg. Gnd
Xtale	8	9	Xtalb

Figure 1. Typical Application as 320 MHz AM Transmitter

NOTES:
1. 50 Ω coaxial balun, 1/10 wavelength at 320 MHz equals 1.5 inches.
2. Pins 5, 10 & 15 are ground and connected to V_{EE} which is the component/DC ground plane side of PCB. These pins must be decoupled to V_{CC}; decoupling capacitors should be placed as close as possible to the pins.
3. The crystal oscillator circuit may be adjusted for frequency with the variable inductor (ML13175); recommended source is Coilcraft "slot seven" 7mm tuneable inductor, Part #7M3–821. 1.0k resistor. Shunting the crystal prevents it from oscillating in the fundamental mode.
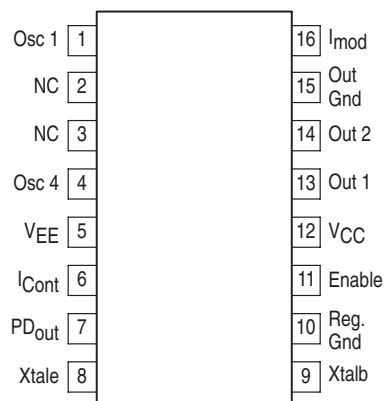
**MAXIMUM RATINGS** (T_A = 25 C, unless otherwise noted.)

Rating	Symbol	Value	Unit
Power Supply Voltage	V_{CC}	7.0 (max)	Vdc
Operating Supply Voltage Range	V_{CC}	1.8 to 5.0	Vdc
Junction Temperature	T_J	+150	C
Operating Ambient Temperature	T_A	− 40 to + 85	C
Storage Temperature	T_{stg}	− 65 to +150	C

ELECTRICAL CHARACTERISTICS (Figure 2; V_{EE} = − 3.0 Vdc, T_A = 25 C, unless otherwise noted.)*

Characteristic	Pin	Symbol	Min	Typ	Max	Unit
Supply Current (Power down: I_{11} & I_{16} = 0)	–	I_{EE1}	− 0.5	–	–	μA
Supply Current (Enable [Pin 11] to V_{CC} thru 30 k, I_{16} = 0)	–	I_{EE2}	–	−14	−18	mA
Total Supply Current (Transmit Mode) (I_{mod} = 2.0 mA; f_o = 320 MHz)	–	I_{EE3}	–	− 34	−39	mA
Differential Output Power (f_o = 320 MHz; V_{ref} [Pin 9] = 500 mV_{p-p}; f_o = N x f_{ref}) I_{mod} = 2.0 mA (see Figure 7, 8) I_{mod} = 0 mA	13 & 14	P_{out}	2.0 –	+ 4.7 − 45	– –	dBm

Hold–in Range (± Δf_{ref} x N)
   ML13175 (see Figure 7)
   ML13176 (see Figure 8)
	13 & 14	± Δf_H	3.5
			4.0
				6.5
				8.0
					–
					–
						MHz

Phase Detector Output Error Current
   ML13175
   ML13176
	7	I_{error}	20
			22
				25
				27
					–
					–
						μA

Oscillator Enable Time (see Figure 22b)	11 & 8	t_{enable}	–	4.0	–	ms
Amplitude Modulation Bandwidth (see Figure 24)	16	BW_{AM}	–	25	–	MHz
Spurious Outputs (I_{mod} = 2.0 mA) Spurious Outputs (I_{mod} = 0 mA)	13 & 14 13 & 14	P_{son} P_{soff}	– –	− 50 − 50	– –	dBc
Maximum Divider Input Frequency Maximum Output Frequency	– 13 & 14	f_{div} f_o	– –	950 950	– –	MHz

* For testing purposes, V_{CC} is ground (see Figure 2).

Figure 2. 320 MHz Test Circuit
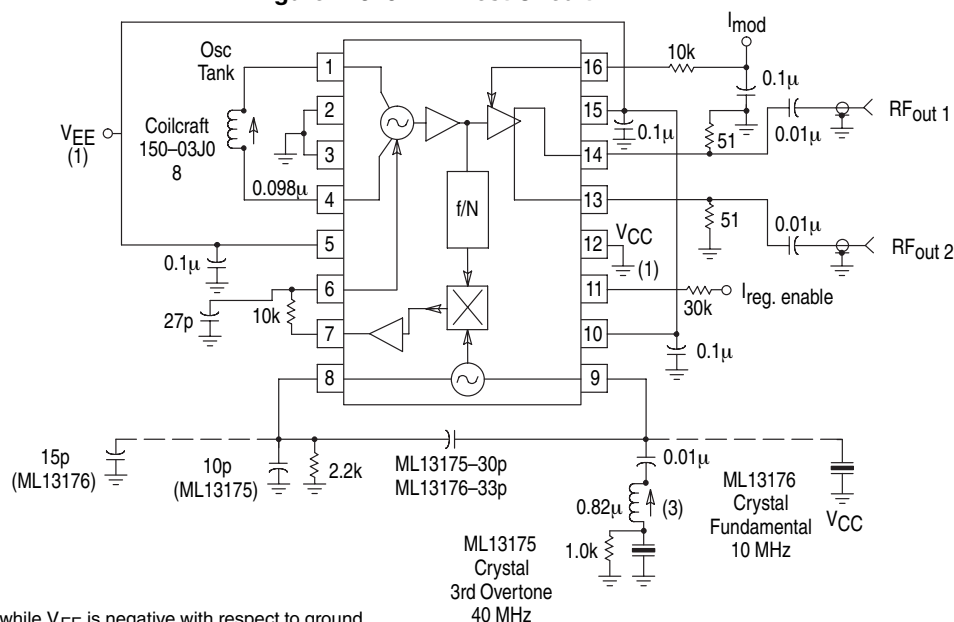
NOTES: 1. V_{CC} is ground; while V_{EE} is negative with respect to ground.
2. Pins 5, 10 and 15 are brought to the circuit side of the PCB via plated through holes.
   They are connected together with a trace on the PCB and each Pin is decoupled to V_{CC} (ground).
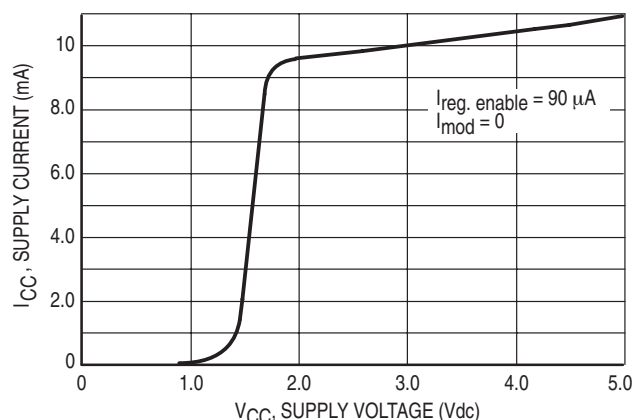3. Recommended source is Coilcraft "slot seven inductor" part number 7M3–821.

PIN FUNCTION DESCRIPTIONS

| Pin	Symbol	Internal Equivalent Circuit	Description/External Circuit Requirements
1 & 4	Osc 1, Osc 4		**CCO Inputs** The oscillator is a current controlled type. An external oscillator coil is connected to Pins 1 and 4 which forms a parallel resonance LC tank circuit with the internal capacitance of the IC and with parasitic capacitance of the PC board. Three base–emitter capacitances in series configuration form the capacitance for the parallel tank. These are the base–emitters at Pins 1 and 4 and the base–emitter of the differential amplifier. The equivalent series capacitance in the differential amplifier is varied by the modulating current from the frequency control circuit (see Pin 6, internal circuit). A more thorough discussion is found in the Applications Information section.
5	V_{EE}		**Supply Ground (V_{EE})** In the PCB layout, the ground pins (also applies to Pins 10 and 15) should be connected directly to chassis ground. Decoupling capacitors to V_{CC} should be placed directly at the ground returns.
6	I_{Cont}		**Frequency Control** For V_{CC} = 3.0 Vdc, the voltage at Pin 6 is approximately 1.55 Vdc. The oscillator is current controlled by the error current from the phase detector. This current is amplified to drive the current source in the oscillator section which controls the frequency of the oscillator. Figures 9 and 10 show the Δf_{osc} versus I_{Cont}, Figure 5 shows the Δf_{osc} versus I_{Cont} at – 40°C, + 25°C and + 85°C for 320 MHz. The CCO may be FM modulated as shown in Figure 17, ML13176 320 MHz FM Transmitter. A detailed discussion is found in the Applications Information section.
7	PD_{out}		**Phase Detector Output** The phase detector provides ± 30 μA to keep the CCO locked at the desired carrier frequency. The output impedance of the phase detector is approximately 53 kΩ. Under closed loop conditions there is a DC voltage which is dependent upon the free running oscillator and the reference oscillator frequencies. The circuitry between Pins 7 and 6 should be selected for adequate loop filtering necessary to stabilize and filter the loop response. Low pass filtering between Pin 7 and 6 is needed so that the corner frequency is well below the sum of the divider and the reference oscillator frequencies, but high enough to allow for fast response to keep the loop locked. Refer to the Applications Information section regarding loop filtering and FM modulation.

PIN FUNCTION DESCRIPTIONS

Pin	Symbol	Internal Equivalent Circuit	Description/External Circuit Requirements
8	Xtale		**Crystal Oscillator Inputs**
9	Xtalb		The internal reference oscillator is configured as a common emitter Colpitts. It may be operated with either a fundamental or overtone crystal depending on the carrier frequency and the internal prescaler. Crystal oscillator circuits and specifications of crystals are discussed in detail in the applications section. With V_{CC} = 3.0 Vdc, the voltage at Pin 8 is approximately 1.8 Vdc and at Pin 9 is approximately 2.3 Vdc. 500 to 1000 mVp–p should be present at Pin 9. The Colpitts is biased at 200 µA; additional drive may be acquired by increasing the bias to approximately 500 µA. Use 6.2 k from Pin 8 to ground.
10	Reg. Gnd		**Regulator Ground**
			An additional ground pin is provided to enhance the stability of the system. Decoupling to the V_{CC} (RF ground) is essential; it should be done at the ground return for Pin 10.
11	Enable		**Device Enable**
			The potential at Pin 11 is approximately 1.25 Vdc. When Pin 11 is open, the transmitter is disabled in a power down mode and draws less than 1.0 µA I_{CC} if the MOD at Pin 16 is also open (i.e., it has no current driving it). To enable the transmitter a current source of 10 µA to 90 µA is provided. Figures 3 and 4 show the relationship between I_{CC}, V_{CC} and $I_{reg.\ enable}$. Note that I_{CC} is flat at approximately 10 mA for $I_{reg.\ enable}$ = 5.0 to 100 µA (I_{mod} = 0).
12	V_{CC}		**Supply Voltage (V_{CC})**
			The operating supply voltage range is from 1.8 Vdc to 5.0 Vdc. In the PCB layout, the V_{CC} trace must be kept as wide as possible to minimize inductive reactances along the trace; it is best to have it completely fill around the surface mount components and traces on the circuit side of the PCB.
13 & 14	Out 1 and Out 2		**Differential Output**
			The output is configured differentially to easily drive a loop antenna. By using a transformer or balun, as shown in the application schematic, the device may then drive an unbalanced low impedance load. Figure 6 shows how much the Output Power and Free–Running Oscillator Frequency change with temperature at 3.0 Vdc; I_{mod} = 2.0 mA.
15	Out_Gnd		**Output Ground**
			This additional ground pin provides direct access for the output ground to the circuit board V_{EE}.
16	I_{mod}		**AM Modulation/Power Output Level**
			The DC voltage at this pin is 0.8 Vdc with the current source active. An external resistor is chosen to provide a source current of 1.0 to 3.0 mA, depending on the desired output power level at a given V_{CC}. Figure 23 shows the relationship of Power Output to Modulation Current, I_{mod}. At V_{CC} = 3.0 Vdc, 3.5 dBm power output can be acquired with about 35 mA I_{CC}. For FM modulation, Pin 16 is used to set the desired output power level as described above. For AM modulation, the modulation signal must ride on a positive DC bias offset which sets a static (modulation off) modulation current. External circuitry for various schemes is further discussed in the Applications Information section.

The internal circuit diagrams referenced:

Pin 8/9 (Crystal Oscillator): V_{CC}, Xtalb (9), Xtale (8), 8.0k, 12k, 4.0k

Pin 10/11 (Regulator Ground / Enable): V_{CC}, 11 Enable, Reg, 5.0p, Subcon, 8.0k, 2.4k, 10 Reg. Gnd

Pin 12 (V_{CC}): V_{CC}, 12 V_{CC}

Pin 13–16 (Output): V_{CC}, 13 Out 1, 14 Out 2, 16 I_{mod}, 15 Out_Gnd
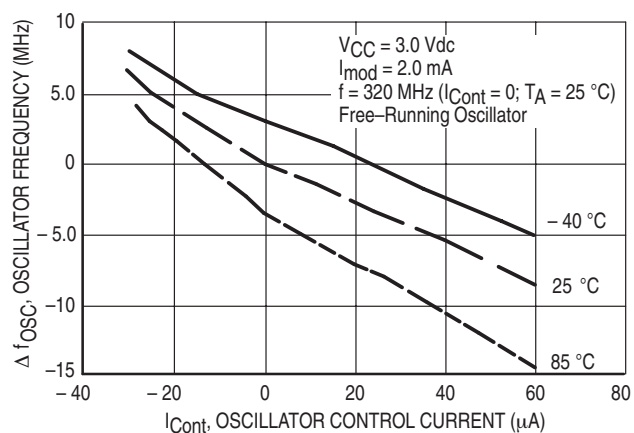
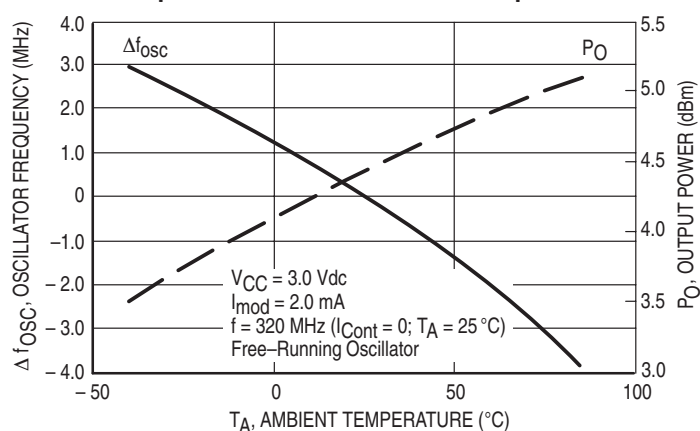**Figure 3. Supply Current
versus Supply Voltage**

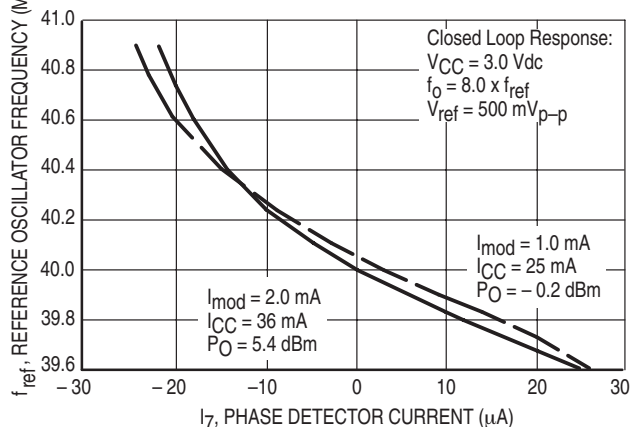**Figure 4. Supply Current versus
Regulator Enable Current**
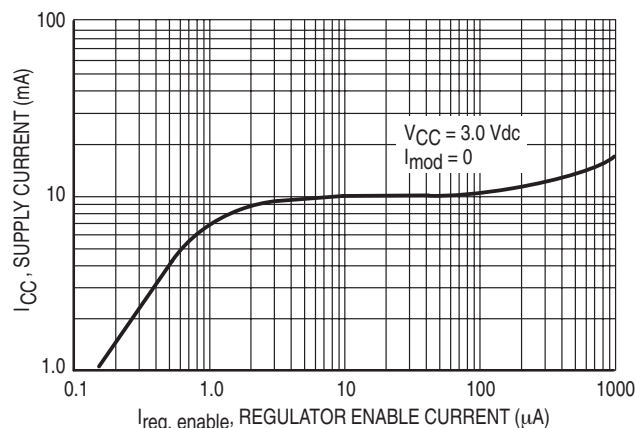
**Figure 5. Change Oscillator Frequency
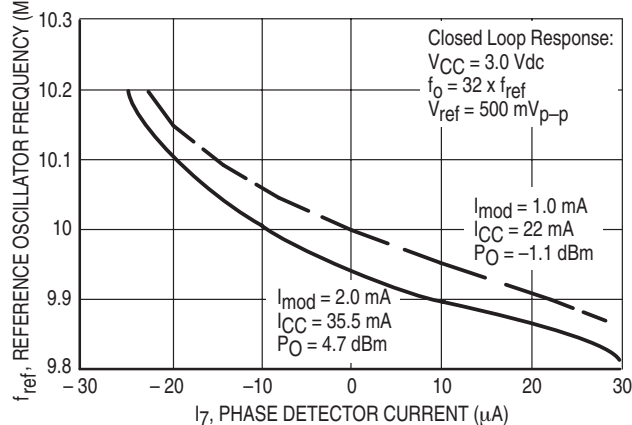versus Oscillator Control Current**

**Figure 6. Change in Oscillator Frequency and
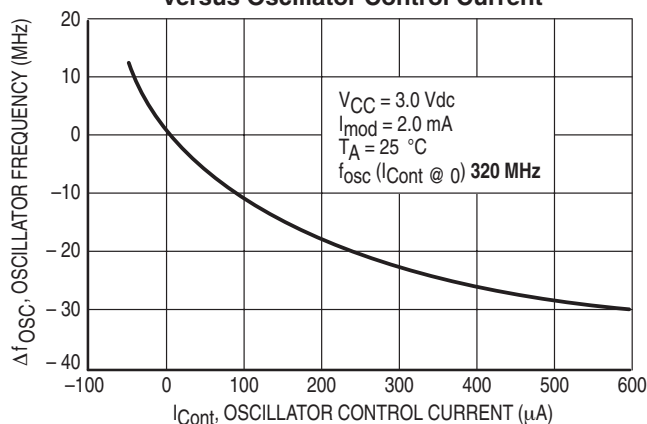Output Power versus Ambient Temperature**

**Figure 7. ML13175 Reference Oscillator
Frequency versus Phase Detector Current**

**Figure 8. ML13176 Reference Oscillator
Frequency versus Phase Detector Current**

Figure 9. Change in Oscillator Frequency versus Oscillator Control Current

V_{CC} = 3.0 Vdc
I_{mod} = 2.0 mA
T_A = 25 °C
f_{osc} (I_{Cont} @ 0) **320 MHz**

Figure 10. Change in Oscillator Frequency versus Oscillator Control Current

V_{CC} = 3.0 Vdc
I_{mod} = 2.0 mA
T_A = 25 °C
f_{osc} (I_{Cont} @ 0) **450 MHz**
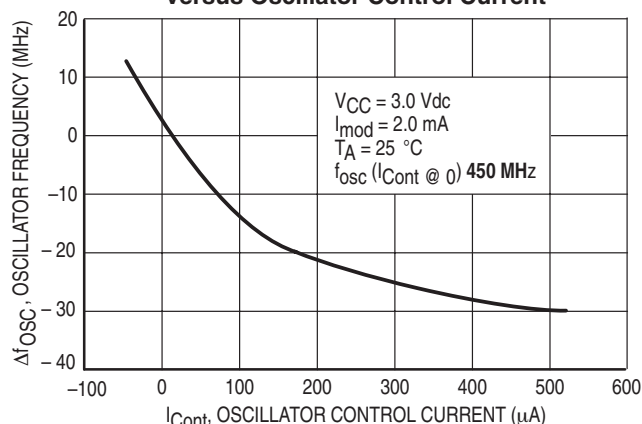
Legacy Applications Information

APPLICATIONS INFORMATION

EVALUATION PC BOARD

The evaluation PCB, shown in Figures 26 and 27, is very versatile and is intended to be used across the entire useful frequency range of this device. The center section of the board provides an area for attaching all SMT components to the component ground side of the PCB (see Figures 28 and 29). Additionally, the peripheral area surrounding the RF core provides pads to add supporting and interface circuitry as a particular application requires. This evaluation board will be discussed and referenced in this section.

CURRENT CONTROLLED OSCILLATOR (Pins 1 to 4)

It is critical to keep the interconnect leads from the CCO (Pins 1 and 4) to the external inductor symmetrical and equal in length. With a minimum inductor, the maximum free running frequency is greater than 1.0 GHz. Since this inductor will be small, it may be either a microstrip inductor, an air wound inductor or a tuneable RF coil. An air wound inductor may be tuned by spreading the windings, whereas tunable RF coils are tuned by adjusting the position of an aluminum core in a threaded coilform. As the aluminum core coupling to the windings is increased, the inductance is decreased. The temperature coefficient using an aluminum core is better than a ferrite core. The UniCoil™ inductors made by Coilcraft may be obtained with aluminum cores (Part No. 51–129–169).

GROUND (Pins 5, 10 and 15)

GROUND RETURNS: It is best to take the grounds to a backside ground plane via plated through holes or eyelets at the pins. The application PCB layout implements this technique. Note that the grounds are located at or less than 100 mils from the device pins.

DECOUPLING: Decoupling each ground pin to V_{CC} isolates each section of the device by reducing interaction between sections and by localizing circulating currents.

LOOP CHARACTERISTICS (Pins 6 and 7)

Figure 11 is the component block diagram of the ML1317x PLL system where the loop characteristics are described by the gain constants. Access to individual components of this PLL system is limited, inasmuch as the loop is only pinned out at the phase detector output and the frequency control input for the CCO. However, this allows for characterization of the gain constants of these loop components. The gain constants K_p, K_O and K_n are well defined in the ML13175 and ML13176.

PHASE DETECTOR (Pin 7)

With the loop in lock, the difference frequency output of the phase detector is DC voltage that is a function of the phase difference. The sinusoidal type detector used in the IC has the following transfer characteristic:

$$\ell_e = A \ Sin \ \theta_e$$

The gain factor of the phase detector, K_p (with the loop in lock) is specified as the ratio of DC output current, le to phase error, θ_e:

$$K_p = \ell_e/\theta_e \ (Amps/radians)$$
$$K_p = A \ Sin \ \theta_e/\theta_e$$
$$Sin \ \theta_e \sim \theta_e \ for \ \theta_e \leq 0.2 \ radians;$$
$$thus \ K_p = A \ (Amps/radians)$$

Figures 7 and 8 show that the detector DC current is approximately 30 μA where the loop loses lock at θe = ±π/2 radians; therefore K_p is 30 μA/radians.

CURRENT CONTROLLED OSCILLATOR, CCO (Pin 6)

Figures 9 and 10 show the non–linear change in frequency of the oscillator over an extended range of control current for 320 and 450 MHz applications. K_O ranges from approximately 6.3×10^5 rad/sec/μA or 100 kHz/μA (Figure 9) to 8.8×10^5 rad/sec/μA or 140 kHz/μA (Figure 10) over a relatively linear response of control current (0 to 100 μA). The oscillator gain factor depends on the operating range of the control current (i.e., the slope is not constant). Included in the CCO gain factor is the internal amplifier which can sink and source at least 30μA of input current from the phase detector. The internal circuitry at Pin 6 limits the CCO control current to 50 μA of source capability while its sink capability exceeds 200 μA as shown in Figures 9 and 10. Further information to follow shows how to use the full capabilities of the CCO by addition of an external loop amplifier and filter (see Figure 15). This additional circuitry yields at K_O = 0.145 MHz/μA or 9.1×10^5 rad/sec/μA.

Legacy Applications Information

Figure 11. Block Diagram of ML1317x PLL
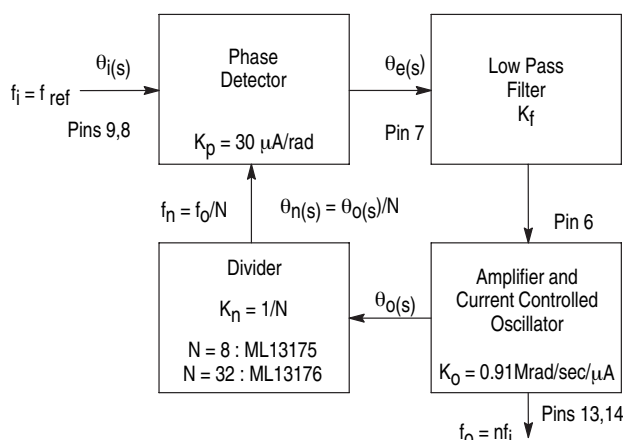
Where: K_p = Phase detector gain constant in
μA/rad; K_p = 30 μA/rad
K_f = Filter transfer function
K_n = 1/N; N = 8 for the MC13175 and
K_o N = 32 for the MC13176
= CCO gain constant in rad/sec/μA
K_o = 9.1 x 10^5 rad/sec/μA

LOOP FILTERING

The fundamental loop characteristics, such as capture range, loop bandwidth, lock–up time and transient response are controlled externally by loop filtering.

The natural frequency (ω_n) and damping factor ($\mathscr{L}$) are important in the transient response to a step input of phase or frequency. For a given $\mathscr{L}$ and lock time wn can be determined from the plot shown in Figure 12.

Figure 12. Type 2 Second Order Response
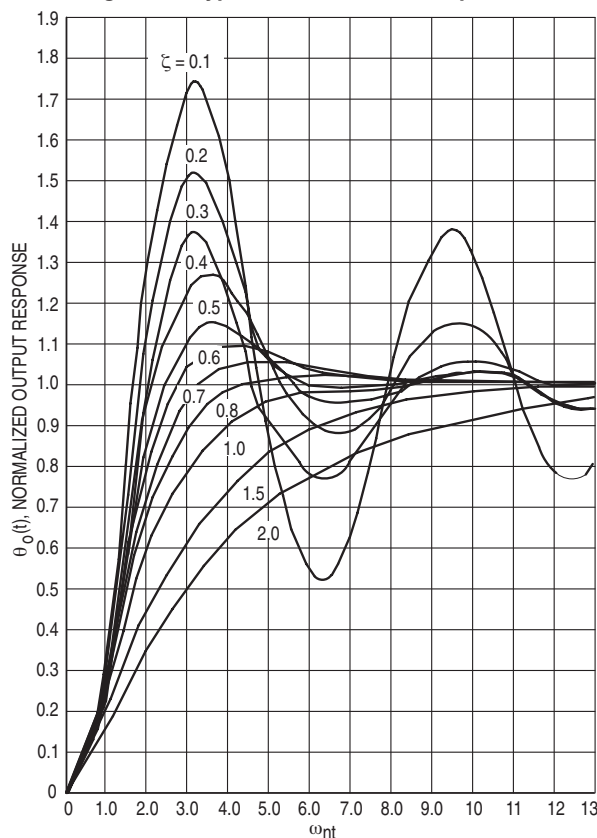
For $\mathscr{L}$ = 0.707 and lock time = 1.0 ms;
then ω = 5.0/t = 5.0 krad/sec.

The loop filter may take the form of a simple low pass filter or a lag–lead filter which creates an additional pole at origin in the loop transfer function. This additional pole along with that of the CCO provides two pure integrators ($1/s^2$). In the lag–lead low pass network shown in Figure 13, the values of the low pass filtering parameters R_1, R_2 and C determine the loop constants ω_n and $\mathscr{L}$. The equations $t_1 = R_1 C$ and $t_2 = R_2 C$ are related in the loop filter transfer functions   F(s) = 1 + $t_2 s/1 + (t_1 + t_2)s$.

Figure 13. Lag–Lead Low Pass Filter
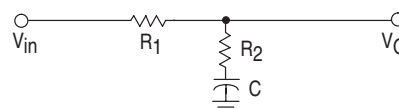
The closed loop transfer function takes the form of a 2nd order low pass filter given by,
$$H(s) = K_V F(s)/s + K_V F(s)$$
From control theory, if the loop filter characteristic has F(0) = 1, the DC gain of the closed loop, K_V is defined as,
$$K_V = K_p K_o K_n$$
and the transfer function has a natural frequency,
$$\omega n = K_V/t_1 + t_2)^{1/2}$$
and a dampning factor,
$$\mathscr{L} = (\omega_n/2)(t_2 + 1 K_V)$$
Rewriting the above equations and solving for the ML13176 with $\mathscr{L}$ = 0.707 and ω_n = 5.0 k rad/sec.
$$K_V = K_p K_o K_n = (30)(0.91 \times 10^6)(1/32) = 0.853 \times 10^6$$
$$t_1 + t_2 = K_V/\omega_n 2 = 0.853 \times 10^6/(25 \times 106) = 34.1 \text{ ms}$$
$$t_2 = 2\mathscr{L}/\omega_n = (2)(0.707)/(5 \times 10^3) = 0.283 \text{ ms}$$
$$t_1 = (K_V/\omega_n 2) - t_2 = (34.1 - 0.283) = 33.8 \text{ ms}$$

Legacy Applications Information

For C = 0.47 μ:

then $R_1 = t_1/C = 33.8 \times 10^{-3}/0.47 \times 10^{-6} = 72$ k

thus, $R_2 = t_2/C = 0.283 \times 10^{-3}/0.47 \times 10^{-6} = 0.60$k

In the above example, the following standard value components are used,

C = 0.47 μf; R_2 = 620 and R'_1 = 72 kΩ – 53 kΩ ~ 18 kΩ (R'_1 is defined as R_1 – 53 kΩ, the output impedance of the phase detector.)

Since the output of the phase detector is high impedance (~50 k) and serves as a current source, and the input to the frequency control, Pin 6 is low impedance (impedance of the two diode to ground is approximately 500 Ω), it is imperative that the second order low pass filter design above be modified. In order to minimize loading of the R_2C shunt network, a higher impedance must be established to Pin 6. A simple solution is achieved by adding a low pass network between the passive second order network and the input to Pin 6. This helps to minimize the loading effects on the second order low pass while further suppressing the sideband spurs of the crystal oscillator. A low pass filter with R_3 = 1.0 k and C_2 - 1500 p has a corner frequency (f_c) of 106 kHz; the reference sideband spurs are down greater than – 60 dBc.

Figure 14. Modified Low Pass Loop Filter
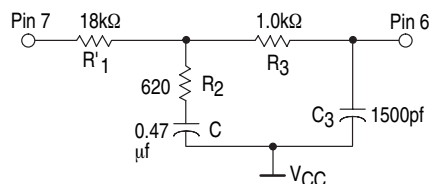
HOLD–IN RANGE

The hold–in range, also called the lock range, tracking range and synchronization range, is the ability of the CCO frequency, f_o to track the input reference signal, fref • N as it gradually shifted away from the free running frequency, f_f. Assuming that the CCO is capable of sufficient frequency deviation and that the internal loop amplifier and filter are not overdriven, the CCO will track until the phase error, θe approaches ±π/2 radians. Figures 5

through 8 are a direct measurement of the hold–in range (i.e. $\Delta f_{ref} \times N = \pm \Delta f_H \times 2\pi$). Since sin θ_e cannot exceed ±1.0, as θ_e approaches ±π/2 the hold–in range is equal to the DC loop gain $K_V \times N$.

$$\pm \Delta \omega_H = \pm K_V \times N$$

where, $K_V = K_p K_o K_n$.

In the above example,

$$\pm \Delta \omega_H = \pm 27.3 \text{ Mrad/sec}$$
$$\pm \Delta f_H = \pm 4.35 \text{ MHz}$$

EXTENDED HOLD–IN RANGE

The hold–in range of about 3.4% could cause problems over temperature in cases where the free–running oscillator drifts more than 2 to 3% because of relatively high temperature coefficients of the ferrite tuned CCO inductor. This problem might worsen for lower frequency applications where the external tuning coil is large compared to internal capacitance at Pins 1 and 4. To improve hold–in range performance, it is apparent that the gain factors involved must be carefully considered.

K_n = is either 1/8 in the ML13175 or 1/32 in the ML13176

K_p = is fixed internally and cannot be altered.

K_o = Figures 9 and 10 suggest that there is capability of greater control range with more current swing. However, this swing must be symmetrical about the center of the dynamic response. The suggested zero current operating point for ±100 μA swing of the CCO is at about + 70 μA offset point.

Ka = External loop amplification will be necessary since the phase detector only supplies ±30 μA.

In the design example in Figure 15, an external resistor (R_5) of 15 kΩ to V_{CC} (3.0 Vdc) provides approximately 100 μA of current boost to supplement the existing 50 μA internal source current. R_4 (1.0 kΩ) is selected for approximately 0.1 Vdc across it with 100 μA. R_1, R_2 and R_3 are selected to set the potential at Pin 7 and the base of 2N4402 at approximately 0.9 Vdc and the emitter at 1.55 Vdc when error current to Pin 6 is approximately zero μA. C_1 is chosen to reduce the level of the crystal sidebands.

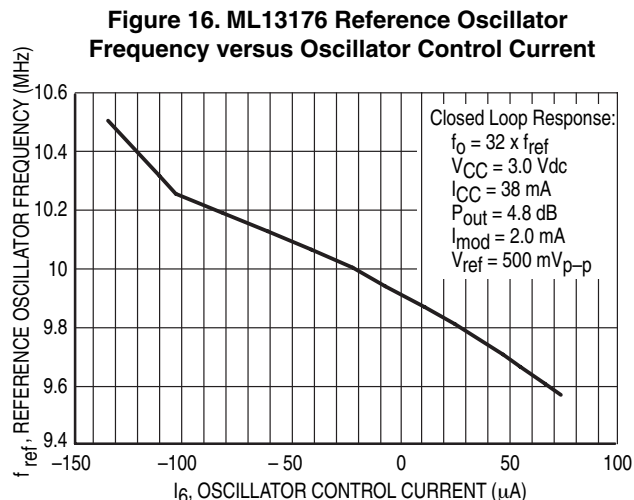**Figure 15. External Loop Amplifier**
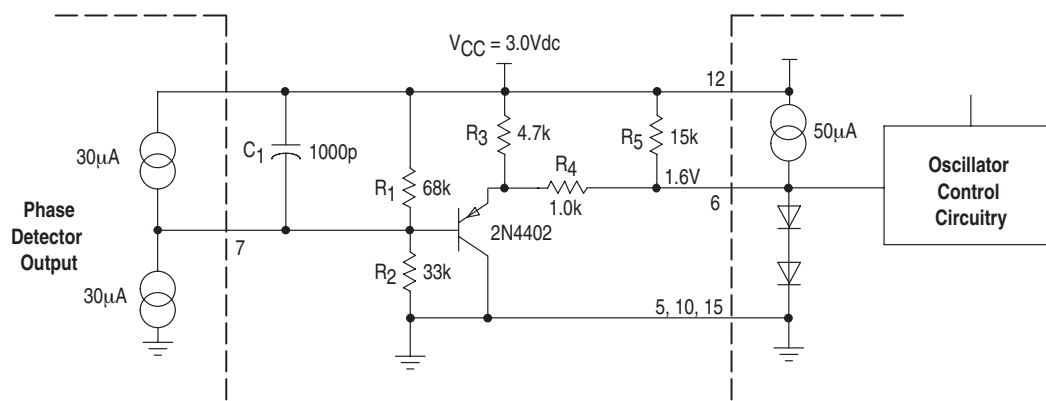
Legacy Applications Information

Figure 16 Shows the improved hold–in range of the loop. The Δfref is moved 950 kHz with over 200 μA swing of control current for an improved hold–in range of ±15.2 MHz or ±95.46 Mrad/sec.

Figure 16. ML13176 Reference Oscillator Frequency versus Oscillator Control Current

Closed Loop Response:
$f_O = 32 \times f_{ref}$
$V_{CC} = 3.0$ Vdc
$I_{CC} = 38$ mA
$P_{out} = 4.8$ dB
$I_{mod} = 2.0$ mA
$V_{ref} = 500$ mV$_{p-p}$

LOCK–IN RANGE/CAPTURE RANGE
If a signal is applied to the loop not equal to free running frequency, f_f, then the loop will capture or lock–in the signal by making $f_S = f_O$ (i.e. if the initial frequency difference is not too great). The lock–in range can be expressed as $\Delta\omega_L \sim \pm 2\mathscr{L}\omega_n$.

FM MODULATION
Noise external to the loop (phase detector input) is minimized by narrowing the bandwidth. This noise if minimal in a PLL system since the reference frequency is usually derived from a crystal oscillator. FM can be achieved by applying a modulation current superimposed on the control current of the CCO. The loop bandwidth must be narrow enough to prevent the loop from responding to the modulation frequency components, thus, allowing the CCO to deviate in frequency. The loop bandwidth is related to the natural frequency wn. In the lag–lead design example where the natural frequency, $\omega n = 5.0$ krad/sec and a damping factor, $\mathscr{L} = 0.707$, the loop bandwidth = 1.64 kHz. Characterization data of the closed loop responses for both the ML13175 and ML13176 at 320 MHz (Figures 7 and 8, respectively) show satisfactory performance using only a simple low–pass loop filter network. The loop filter response is strongly influenced by the high output impedance of the push–pull current output of the phase detector.

$f_C = 0.159/RC$;
For $R = 1.0$ k $+ R_7$ ($R_7 = 53$ k) and $C = 390$ pF
$f_C = 7.55$ kHz or $\omega_C = 47$ krad/sec

The application example in Figure 17a of a 320 MHz FM transmitter demonstrates the FM capabilities of the IC. A high value series resistor (100 k) to Pin 6 sets up the current source to drive the modulation section of the chip. Its value is dependent on the peak to peak level of the encoding data and the maximum desired frequency deviation. The data input is AC coupled with a large coupling capacitor which is selected for the modulating frequency. The component placements on the circuit side and ground side of the PC board are shown in Figures 28 and 29 respectively.

For voice application using a dynamic or an electret microphone, an op amp is used to amplify the microphone's low level output . The microphone amplifier circuit is shown in Figure 19. Figure 17b shows an application example for NBFM audio or direct FSK in which the reference crystal oscillator is modulated.

Figure 19. Microphone Amplifier
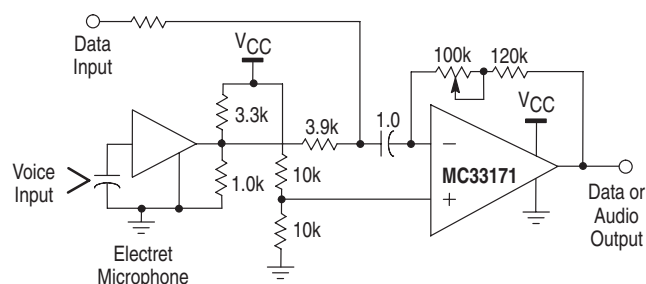
LOCAL OSCILLATOR APPLICATION
To reduce internal loop noise, a relatively wide loop bandwidth is needed so that the loop tracks out or cancels the noise. This is emphasized to reduce inherent CCO and divider noise or noise produced by mechanical shock and environmental vibrations. In a local oscillator application the CCO and divider noise should be reduced by proper selection of the natural frequency of the loop. Additional low pass filtering of the output will likely be necessary to reduce the crystal sideband spurs to a minimal level.

Legacy Applications Information

Figure 17a. 320 MHz ML13176 FM Transmitter
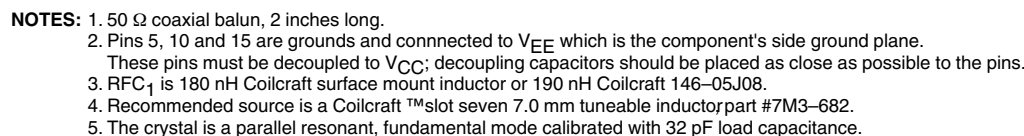
NOTES: 1. 50 Ω coaxial balun, 2 inches long.
2. Pins 5, 10 and 15 are grounds and connnected to V_{EE} which is the component's side ground plane.
   These pins must be decoupled to V_{CC}; decoupling capacitors should be placed as close as possible to the pins.
3. RFC_1 is 180 nH Coilcraft surface mount inductor or 190 nH Coilcraft 146–05J08.
4. Recommended source is a Coilcraft ™slot seven 7.0 mm tuneable inductor part #7M3–682.
5. The crystal is a parallel resonant, fundamental mode calibrated with 32 pF load capacitance.

Figure 17b. 320 MHz NBFM Transmitter

NOTES: 1. 50 Ω coaxial balun, 2 inches long.
2. Pins 5, 10 and 15 are grounds and connnected to V_{EE} which is the component's side ground plane. These
   pins must be decoupled to V_{CC}; decoupling capacitors should be placed as close as possible to the pins.
3. RFC_1 is 180 nH Coilcraft surface mount inductor.
4. RFC_2 and RFC_3 are high impedance crystal frequency of 10 MHz; 8.2 μH molded inductor gives XL > 1000 Ω..
5. A single varactor like the MV2105 may be used whereby RFC_2 is not needed.
6. The crystal is a parallel resonant, fundamental mode calibrated with 32 pF load capacitance.

Legacy Applications Information

REFERENCE CRYSTAL OSCILLATOR
(Pins 8 and 9)

Selection of Proper Crystal: A crystal can operate in a number of mechanical modes. The lowest resonant frequency mode is its fundamental while higher order modes are called overtones. At each mechanical resonance, a crystal behaves like a RLC series–tuned circuit having a large inductor and a high Q. The inductor L_S is series resonance with a dynamic capacitor, C_S determined by the elasticity of the crystal lattice and a series resistance Rs, which accounts for the power dissipated in heating the crystal. This series RLC circuit is in parallel with a static capacitance, C_p which is created by the crystal block and by the metal plates and leads that make contact with it.

Figure 20 is the equivalent circuit for a crystal in a signal resonant mode. It is assumed that other modes of resonance are so far off frequency that their effects are negligible.
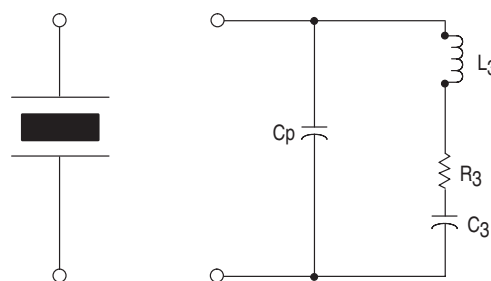
Series resonant frequency, f_S is given by;

$$f_S = 1/2\pi(L_S C_S)^{1/2}$$

and parallel resonant frequency, f_p is given by;

$$f_p = f_S(1 + C_S/C_p)^{1/2}$$

Figure 20. Crystal Equivalent Circuit

the frequency separation at resonance is given by;

$$\Delta f = f_p - f_S = f_S[1 - (1 + C_S/C_p)^{1/2}]$$

Usually f_p is less than 1% higher than fs, and a crystal exhibits an extremely wide variation of the reactance with frequency between f_p and f_S. A crystal oscillator circuit is very stable with frequency. This high rate of change of impedance with frequency stabilizes the oscillator, because any significant change in oscillator frequency will cause a large phase shift in the feedback loop keeping the oscillator on frequency.

Legacy Applications Information

Manufacturers specify crystal for either series or parallel resonant operation. The frequency for the parallel mode is calibrated with a specified shunt capacitance called a "load capacitance." The most common value is 30 to 32 pF. If the load capacitance is placed in series with the crystal, the equivalent circuit will be series resonance at the specified parallel–resonant frequency. Frequencies up to 20 MHz use parallel resonant crystal operating in the fundamental mode, while above 20 MHz to about 60 MHz, a series resonant crystal specified and calibrated for operation in the overtone mode is used.

APPLICATION EXAMPLES
Two types of crystal oscillator circuits are used in the applications circuits: 1) fundamental mode common emitter Colpitts (Figures 1, 17a, 17b and 21) and 2) third overtone impedance inversion Colpitts (also Figures 1 and 21).

The fundamental mode common emitter Colpitts uses a parallel resonant crystal calibrated with a 32 pf load capacitance. The capacitance values are chosen to provide excellent frequency stability and output power of > 500 mVp–p at Pin 9. In Figures 1 and 21, the fundamental mode reference oscillator is fixed tuned relying on the repeatability of the crystal and passive network to maintain the frequency, while in the circuit shown in Figure 17, the oscillator frequency can be adjusted with the variable inductor for the precise operating frequency.

The third overtone impedance inversion Colpitts uses a series resonance crystal with a 25 ppm tolerance. In the application examples (Figures 1 and 21), the reference oscillator operates with the third overtone crystal at 40.0000 MHz. Thus, the ML13175 is operated at 320 MHz ($f_O/8$ = crystal; 320/8) = 40.0000 MHz. The resistor across the crystal ensures that the crystal will operate in the series resonance mode. A tuneable inductor is used to adjust the oscillation frequency; it forms a parallel resonant circuit with the series and parallel combination of the external capacitors forming the divider and feedback network and the base–emitter capacitance of the devices. If the crystal is shorted, the reference oscillator should free–run at the frequency dictated by the parallel resonant LC network.
The reference oscillator can be operated as high as 60 MHz with a third overtone crystal. Therefore, it is possible to use the ML13175 up to at least 480 MHz and the ML13176 up to 950 MHz (based on the maximum capability of the divider netowork).

ENABLER (Pin 11)
The enabling resistor at Pin 11 is calculated by:

$$R_{eg.}\text{ enable} = V_{CC} – 1.0\text{ Vdc}/l_{reg.}\text{ enable}$$

From Figure 4, $l_{reg.enable}$ is chosen to be 75µA. So, for a V_{CC} = 3.0 Vdc $R_{reg.enable}$ = 26.6 kΩ, a standard value 27 kΩ resistor is adequate.

LAYOUT CONSIDERATIONS
Supply (Pin 12): In the PCB layout the V_{CC} trace must be kept as wide as possible to minimize inductive reactance along the trace; it is best that V_{CC} (RF ground) completely fills around the surface mounted components and interconnect traces on the circuit side of the board. This technique is demonstrated in the evaluation PC board.

BATTERY/SELECTION/LITHIUM TYPES
The device may be operated from a 3.0 V lithium battery. Selection of a suitable battery is important. Because one of the major problems for long life battery powered equipment is oxidation of the battery terminals, a battery mounted in clip–in socket is not advised. The battery leads or contact post should be isolated from the air to eliminate oxide build–up. The battery should have PC board mounting tabs which can be soldered to the PCB. Consideration should be given for the peak current capability of the battery. Lithium batteries have current handling capabilities based on the composition of the lithium compound, construction and the battery size. A 1300 mA/hr rating can be achieved in the cylindrical cell battery. The Rayovac CR2/3A lithium–manganese dioxide battery is a crimp sealed, spiral wound 3.0 Vdc, 1300 mA/hr cylindrical cell with PC board mounting tabs. It is an excellent choice based on capacity and size (1.358" long by 0.665" in diameter).

DIFFERENTIAL OUTPUT (Pins 13, 14)
The availability of micro–coaxial cable and small baluns in surface mount and radial–leaded components allows for simple interface to the output ports. A loop antenna may be directly connected with bias via RFC or 50 Ω resistors. Antenna configuration will vary depending on the space available and the frequency of operation.

AM MODULATION (Pin 16)
Amplitude Shift Key: The ML13175 and ML13176 are designed to accommodate Amplitude Shift Keying (ASK). ASK modulation is a form of digital modulation corresponding to AM. The amplitude of the carrier is switched between two or more values in response to the PCM code. For the binary case, the usual choice is On–Off Keying (often abbreviated OOK). The resultant amplitude modulated waveform consists of RF pulses called marks, representing binary 1 and spaces representing binary 0.

Legacy Applications Information

Figure 21. ASK 320 MHz Application Circuit
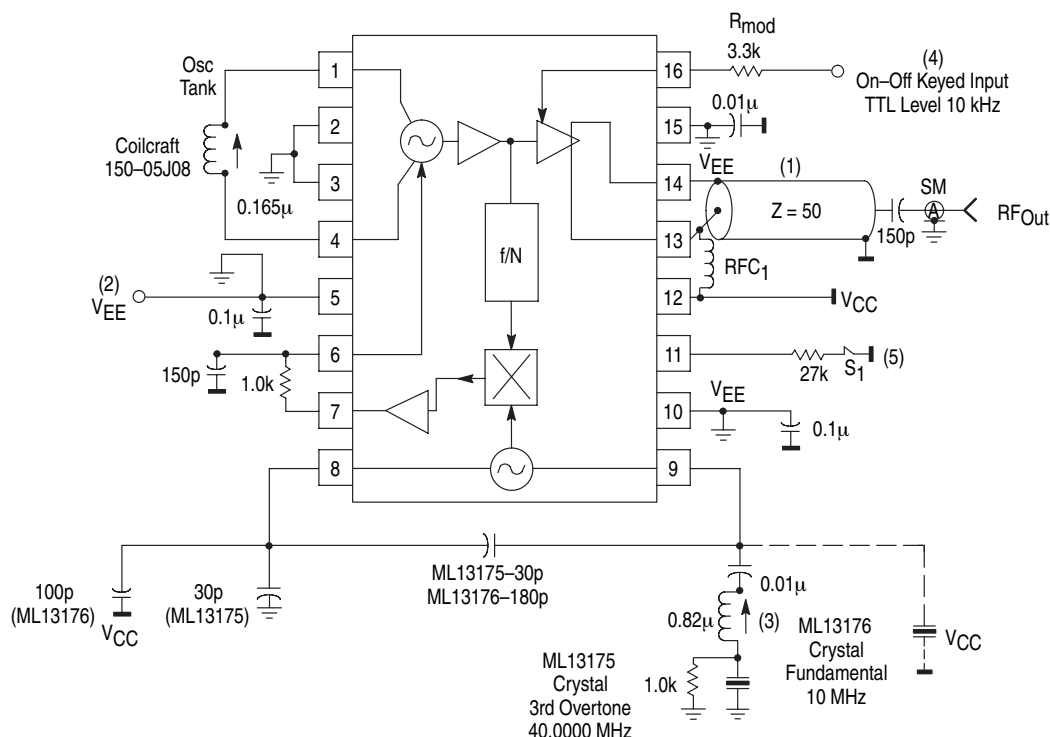
NOTES: 1. 50 Ω coaxial balun, 1/10 wavelength line (1.5") provides the best match to a 50 Ω load.

2. Pins 5, 10 and 15 are ground and connnected to V_{EE} which is the component/DC ground plane side of PCB. These pins must be decoupled to V_{CC}; decoupling capacitors should be placed as close as possible to the pins.

3. The crystal oscillator circuit may be adjusted for frequency with the variable inductor (MC13175); 1.0 k resistor shunting the crystal prevents it from oscillating in the fundamental mode. Recommended source is Coilcraft "slot seven" 7.0 mm tuneable inductor, part #7M3–821.

4. The On–Off keyed signal turns the output of the transmitter off and on with TTL level pulses through R_{mod} at Pin 16. The "On" power and I_{CC} is set by the resistor which sets $I_{mod} = VTTL – 0.8 / R_{mod}$. (see Figure 23).

5. S1 simulates an enable gate pulse from a microprocessor which will enable the transmitter. (see Figure 4 to determine precise value of the enabling resistor based on the potential of the gate pulse and the desired enable.)

Figure 21 shows a typical application in which the output power has been reduced for linearity and current drain. The current draw on the device is 16 mA I_{CC} (average) and –22.5 dBm (average power output) using a 10 kHz modulating rate for the on–off keying. This equates to 20 mA and –2.3 dBm "on", 13 mA and –41 dBm "Off". The crystal oscillator

enable time is needed to set the acquisition timing. It takes typically 4.0 msec to reach full magnitude of the oscillator waveform. A square waveform of 3.0 V peak with a period that is greater than the oscillator enable time is applied to the Enable (Pin 11)

Legacy Applications Information

Figure 23. Power Output versus Modulation Current

V_{CC} = 3.0 Vdc
f = 320 MHz
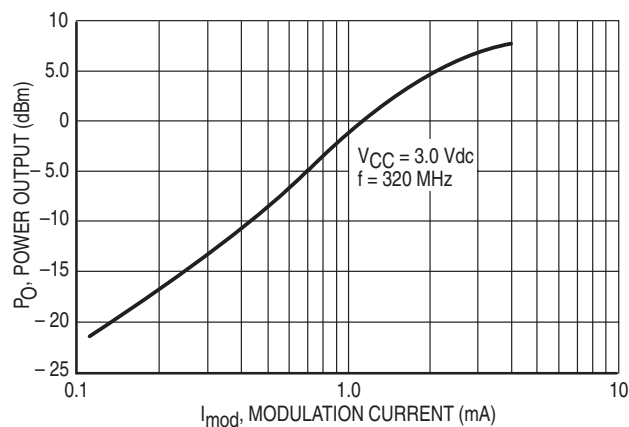
ANALOG AM

In analog AM applications, the output amplifier's linearity must be carefully considered. Figure 23 is a plot of Power Output versus Modulation Current at 320 MHz, 3.0 Vdc. In order to achieve a linear encoding of the modulating sinusoidal waveform on the carrier, the modulating signal must amplitude modulate the carrier in the linear portion of its power output response. When using a sinewave modulating signal, the signal rides on a positive DC offset called Vmod which sets a static (modulation off) modulation current, I_{mod}. I_{mod} controls the power output of the IC. As the modulating signal moves around this static bias point the modulating current varies causing power output to vary or to be AM modulated. When the IC is operated at modulation current levels greater than 2.0 mAdc the differential output stage starts to saturate.

Legacy Applications Information

In the design example, shown in FIgure 24, the operating point is selected as a tradeoff between average power output and quality of the AM.

For V_{CC} = 3.0 Vdc; I_{CC} = 18.5 mA and Imod = 0.5 mAdc and a static DC offset of 1.04 Vdc, the circuit shown in Figure 24 completes the design.

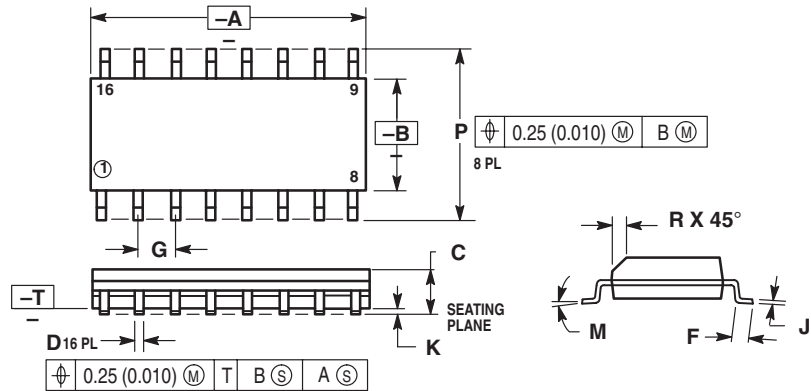Where R_{mod} = (V_{CC} − 1.04 Vdc)/0.5 mA = 3.92 kΩ, use a standard value resistor of 3.9 kΩ.

Figure 24. Analog AM Transmitter
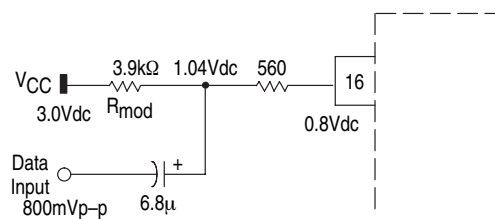
OUTLINE DIMENSIONS

PLASTIC PACKAGE
(ML13175-5P, ML13176-5P)
CASE 751B
(SO–16)

NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: MILLIMETER.
3. DIMENSION A AND B DO NOT INCLUDE MOLD PROTRUSION.
4. MAXIMUM MOLD PROTRUSION 0.15 (0.006) PER SIDE.
5. 751B–01 IS OBSOLETE, NEW STANDARD 751B–03.

DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	9.80	10.00	0.386	0.393
B	3.80	4.00	0.150	0.157
C	1.35	1.75	0.054	0.068
D	0.35	0.49	0.014	0.019
F	0.40	1.25	0.016	0.049
G	1.27 BSC		0.050 BSC	
J	0.19	0.25	0.008	0.009
K	0.10	0.25	0.004	0.009
M	0°	7°	0°	7°
P	5.80	6.20	0.229	0.244
R	0.25	0.50	0.010	0.019

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