

0-600 bps DIGITAL MODEM

The MC6860 is a MOS subsystem designed to be integrated into a wide range of equipment utilizing serial data communications.

The modem provides the necessary modulation, demodulation and supervisory control functions to implement a serial data communications link, over a voice grade channel, utilizing frequency shift keying (FSK) at bit rates up to 600 bps. The MC6860 can be implemented into a wide range of data handling systems, including stand alone modems, data storage devices, remote data communication terminals and I/O interfaces for minicomputers.

N-channel silicon-gate technology permits the MC6860 to operate using a single-voltage supply and be fully TTL compatible.

The modem is compatible with the M6800 microcomputer family, interfacing directly with the Asynchronous Communications Interface Adapter to provide low-speed data communications capability.

- Originate and Answer Mode
- Crystal or External Reference Control
- Modem Self Test
- Terminal Interfaces TTL-Compatible
- Full-Duplex or Half-Duplex Operation
- Automatic Answer and Disconnect
- Compatible Functions for 100 Series Data Sets
- Compatible Functions for 1001A/B Data Couplers

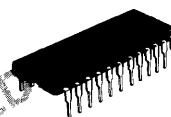
MC6860

MOS

(N-CHANNEL, SILICON-GATE)

0-600 bps DIGITAL MODEM

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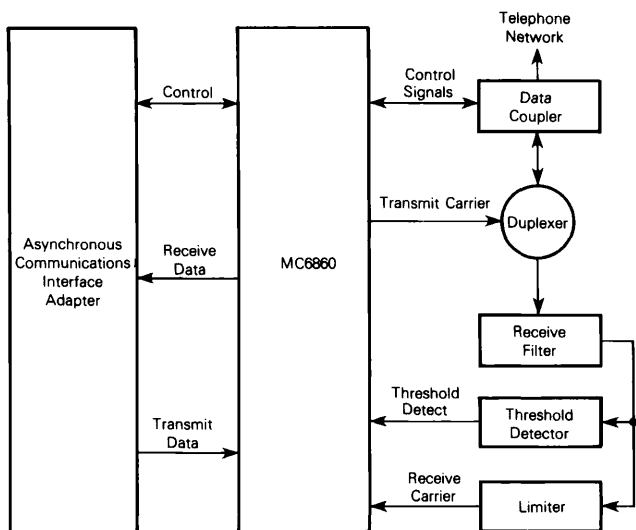


L SUFFIX
 CERAMIC PACKAGE
 CASE 623

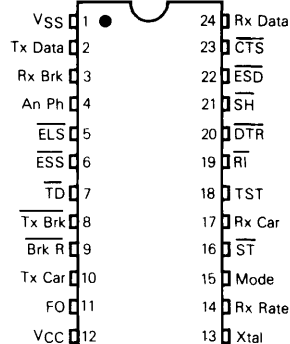


P SUFFIX
 PLASTIC PACKAGE
 CASE 709

FIGURE 1 — TYPICAL MC6860 SYSTEM CONFIGURATION



PIN ASSIGNMENT



MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Supply Voltage	V _{CC}	− 0.3 to + 7.0	V
Input Voltage	V _{in}	− 0.3 to + 7.0	V
Operating Temperature Range	T _A	0 to 70	°C
Storage Temperature Range	T _{stg}	− 55 to + 150	°C

This device contains circuitry to protect the inputs against damage due to high static voltages or electric fields; however, it is advised that normal precautions be taken to avoid application of any voltage higher than maximum rated voltages to this high impedance circuit.

Reliability of operation is enhanced if unused inputs are tied to an appropriate logic voltage level (e.g., either V_{SS} or V_{CC}).

THERMAL CHARACTERISTICS

Characteristics	Symbol	Value	Unit
Thermal Resistance Ceramic Plastic	θ _{JA}	65 120	°C/W

POWER CONSIDERATIONS

The average chip-junction temperature, T_J, in °C can be obtained from:

$$T_J = T_A + (P_D \cdot \theta_{JA}) \tag{1}$$

Where:

- T_A = Ambient Temperature, °C
- θ_{JA} = Package Thermal Resistance, Junction-to-Ambient, °C/W
- P_D = P_{INT} + P_{PORT}
- P_{INT} = I_{CC} × V_{CC}, Watts — Chip Internal Power
- P_{PORT} = Port Power Dissipation, Watts — User Determined

For most applications P_{PORT} ≪ P_{INT} and can be neglected. P_{PORT} may become significant if the device is configured to drive Darlington bases or sink LED loads.

An approximate relationship between P_D and T_J (if P_{PORT} is neglected) is:

$$P_D = K + (T_J + 273^\circ\text{C}) \tag{2}$$

Solving equations 1 and 2 for K gives:

$$K = P_D \cdot (T_A + 273^\circ\text{C}) + \theta_{JA} \cdot P_D^2 \tag{3}$$

Where K is a constant pertaining to the particular part. K can be determined from equation 3 by measuring P_D (at equilibrium) for a known T_A. Using this value of K the values of P_D and T_J can be obtained by solving equations (1) and (2) iteratively for any value of T_A.

DC ELECTRICAL CHARACTERISTICS

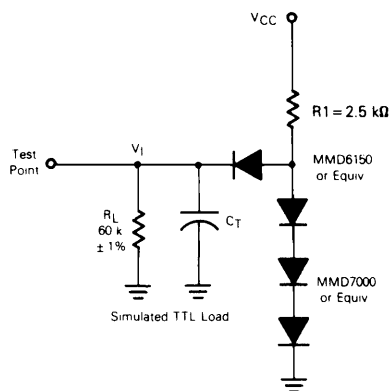
(V_{CC} = 5.0 ± 5% Vdc, all voltages referenced to V_{SS} = 0, T_A = T_L to T_H, all outputs loaded as shown in Figure 2 unless otherwise noted.)

Characteristic	Symbol	Min	Typ	Max	Unit
Input High Voltage, All Inputs Except Crystal	V _{IH}	2.0	—	V _{CC}	V
Input Low Voltage, All Inputs Except Crystal	V _{IL}	V _{SS}	—	0.80	V
Crystal Input Voltage (Crystal Input Driven from an External Reference, Input Coupling Capacitor = 200 pF, Duty Cycle = 50 ± 5%)	V _{in}	1.5	—	2.0	V _{p-p}
Input Current (V _{in} = V _{SS}) All Inputs Except Rx Car, Tx Data, $\overline{\text{TD}}$, $\overline{\text{TST}}$, $\overline{\text{RI}}$, $\overline{\text{SH}}$ RI, SH Inputs	I _{in}	—	—	−0.2 −1.6	mA
Input Leakage Current (V _{in} = 7.0 V, V _{CC} = V _{SS} , T _A = 25°C)	I _{IL}	—	—	1.0	μA
Output High Voltage, All Outputs Except An Ph and Tx Car (I _{OH1} = −0.04 mA, Load A)	V _{OH1}	2.4	—	V _{CC}	V
Output Low Voltage, All Outputs Except An Ph and Tx Car (I _{OL1} = 1.6 mA, Load A)	V _{OL1}	V _{SS}	—	0.40	V
Output High Current, An Ph (V _{OH2} = 0.8 V, Load B)	I _{OH2}	0.30	—	—	mA
Output Low Voltage, An Ph (I _{OL2} = 0, Load B)	V _{OL2}	V _{SS}	—	0.30	V
Input Capacitance (f = 0.1 MHz, T _A = 25°C)	C _{in}	—	5.0	—	pF
Output Capacitance (f = 0.1 MHz, T _A = 25°C)	C _{out}	—	10	—	pF
Transmit Carrier Output Voltage (Load C)	V _{CO}	0.20	0.35	0.50	V(RMS)
Transmit Carrier Output 2nd Harmonic (Load C)	V _{2H}	−25	−32	—	dB
Input Transition Times, All Inputs Except Crystal (Operating in the Crystal Input Mode; from 10% to 90% Points)	t _r t _f	— —	— —	1.0* 1.0*	μs
Input Transition Times, Crystal Input (Operating in External Input Reference Model)	t _r t _f	— —	— —	30 30	ns
Output Transition Times, All Outputs Except Tx Car (From 10% to 90% Points)	t _r t _f	— —	— —	5.0 5.0	μs
Internal Power Dissipation (All Inputs at V _{SS} and All Outputs Open) (Measured at T _A = T _L)	P _{INT}	—	—	340	mW

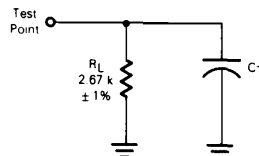
*Maximum Input Transition Times are ≤ 0.1 × Pulse Width or the specified maximum of 1.0 μs, whichever is smaller.

FIGURE 2 — OUTPUT TEST LOADS

Load A — TTL Output Load for Receive Break, Digital Carrier, Mode, Clear-to-Send, and Receive Data Outputs



Load B — Answer Phone Load



Load C — Transmit Carrier Load

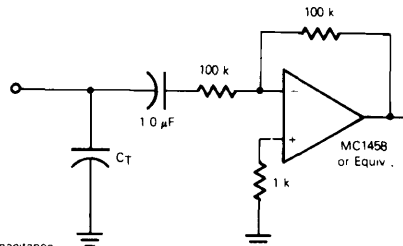
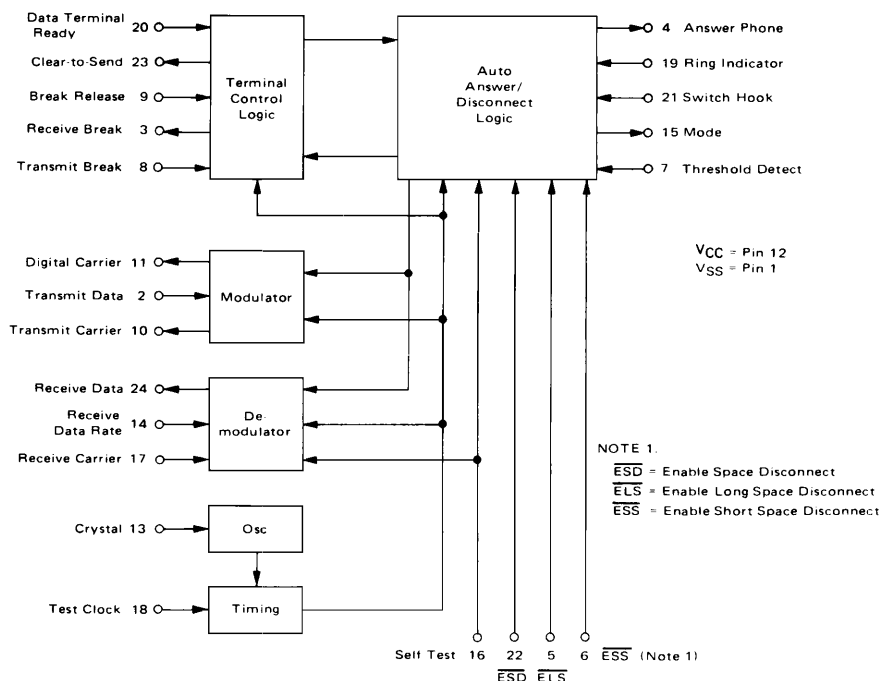
C_T = 20 pF = total parasitic capacitance, which includes probe, wiring, and load capacitance

FIGURE 3 — BLOCK DIAGRAM



DEVICE OPERATION*

GENERAL

Figure 1 shows the modem and its interconnections. The data to be transmitted is presented in serial format to the modulator for conversion to FSK signals for transmission on the telephone line (refer to Figure 3). The modulator output is buffered before driving the line.

The FSK signal from the remote modem is received via the telephone line and filtered to remove extraneous signals such as the local Transmit Carrier. This filtering can be either a bandpass which passes only the desired band of frequencies or a notch which rejects the known interfering signal. The desired signal is then limited to preserve the axis crossings and fed to the demodulator where the data is recovered from the received FSK carrier.

The Supervisory Control provides the necessary commands and responses for handshaking with the remote modem, along with the interface signals to the data coupler and communication terminal. If the modem is a built-in unit,

all input-output (I/O) logic need not be RS-232 compatible. The use of MC1488 and MC1489A line drivers and receivers will provide a RS-232 interface conforming to the EIA specification.

ANSWER MODE

Automatic answering is first initiated by a receipt of a Ring Indicator (RI) signal. This can be either a low level for at least 51 ms as would come from a CBS data coupler, or at least 20 cycles of a 20-47 Hz ringing signal (low level $\geq 50\%$ of the duty cycle) as would come from a CBT data coupler. The presence of the Ring Indicator signal places the modem in the Answer Mode; if the Data Terminal Ready line is low, indicating the communication terminal is ready to send or receive data, the Answer Phone output goes high. This output is designed to drive a transistor switch which will activate

*See Tables 1 and 2 for delay time tolerances.

the Off Hook (OH) and Data Transmission (DA) relays in the data coupler. Upon answering the phone the 2225-Hz Transmit Carrier is turned on.

The originate modem at the other end detects this 2225-Hz signal and after a 450 ms delay (used to disable any echo suppressors in the telephone network) transmits a 1270-Hz signal which the local answering modem detects, provided the amplitude and frequency requirements are met. The amplitude threshold is set external to the modem chip. If the signal level is sufficient the $\overline{\text{TD}}$ input should be low for 20 μs at least once every 32 ms. The absence of a threshold indication for a period greater than 51 ms denotes the loss of Receive Carrier and the modem begins hang-up procedures. Hang-up will occur 17 s after $\overline{\text{RI}}$ has been released provided the handshaking routine is not re-established. The frequency tolerance during handshaking is ± 100 Hz from the Mark frequency.

After the 1270-Hz signal has been received for 150 ms, the Receive Data is unclamped from a Mark condition and data can be received. The Clear-to-Send output goes low 450 ms after the receipt of carrier and data presented to the answer modem is transmitted. Refer to Figure 4.

AUTOMATIC DISCONNECT

Upon receipt of a space of 150 ms or greater duration, the modem clamps the Receive Break high. This condition exists until a Break Release command is issued at the receiving station. Upon receipt of a 0.3 s space, with Enable Short Space Disconnect at the most negative voltage (low), the modem automatically hangs up. If Enable Long Space Disconnect is low, the modem requires 1.5 s of continuous space to hang up. Refer to Figure 5.

ORIGINATE MODE

Upon receipt of a Switch Hook ($\overline{\text{SH}}$) command the modem function is placed in the Originate Mode. If the Data Terminal Ready input is enabled (low) the modem will provide a logic high output at Answer Phone. The modem is now ready to receive the 2225-Hz signal from the remote answering modem. It will continue to look for this signal until 17 s after $\overline{\text{SH}}$ has been released. Disconnect occurs if the handshaking routine is not established.

Upon receiving 2225 \pm 100 Hz for 150 ms at an acceptable amplitude, the receive Data output is unclamped from a Mark condition and data reception can be accomplished. 450 ms after receiving a 2225-Hz signal, a 1270-Hz signal is transmitted to the remote modem. 750 ms after receiving the 2225-Hz signal, the Clear-to-Send output is taken low and data can now be transmitted as well as received. Refer to Figure 6.

INITIATE DISCONNECT

In order to command the remote modem to automatically hang up, a disconnect signal is sent by the local modem. This is accomplished by pulsing the normally low Data Terminal Ready into a high state for greater than 34 ms. The local modem then sends a 3 s continuous space and hangs up provided the Enable Space Disconnect is low. If the remote modem hangs up before 3 s, loss of Threshold Detect will cause loss of Clear-to-Send, which marks the line in Answer Mode and turns the carrier off in the Originate Mode.

If $\overline{\text{ESD}}$ is high the modem will transmit data until hang-up occurs 3 s later. Receive Break is clamped 150 ms following the Data Terminal Ready interrupt. Refer to Figure 7.

INPUT/OUTPUT FUNCTIONS

Figure 8 shows the I/O interface for the low speed modem. The following is a description of each individual signal:

Receiver Carrier (Rx Car)

The Receive Carrier is the FSK input to the demodulator. The local Transmit Carrier must be balanced or filtered out and the remaining signal hard limited. The conditioned receive carrier is measured by the MC6860. Any half-cycle period greater than or equal to 429 \pm 1.0 μs for the low band or 235 \pm 1.0 μs for the high band is detected as a space. Resultant peak phase jitter is as follows:

Data Rate Bits per Second	Answer Mode ϕ_J (Peak %)	Originate Mode ϕ_J (Peak %)
300	7.0	3.7
200	4.7	2.5
150	3.5	1.8
110	2.6	1.4

Ring Indicator ($\overline{\text{RI}}$)

The modem function will recognize the receipt of a call from the CBT data coupler if at least 20 cycles of the 20-47 Hz ringing signal (low level $\geq 50\%$ of the duty cycle) are present. The CBS data coupler $\overline{\text{RI}}$ signal must be level-converted to TTL according to the EIA RS-232 specification before interfacing it with the modem function. The receipt of a call from the CBS data coupler is recognized if the $\overline{\text{RI}}$ signal is present for at least 51 ms. This input is held high except during ringing. An $\overline{\text{RI}}$ signal automatically places the modem function in the Answer Mode.

Switch Hook ($\overline{\text{SH}}$)

$\overline{\text{SH}}$ interfaces directly with the CBT data coupler and via the EIA RS-232 level conversion for the CBS data coupler. An $\overline{\text{SH}}$ signal automatically places the modem function in the Originate Mode.

$\overline{\text{SH}}$ is low during origination of a call. The modem will automatically hang up 17 s after releasing $\overline{\text{SH}}$ if the handshaking routine has not been accomplished.

Threshold Detect ($\overline{\text{TD}}$)

This input is derived from an external threshold detector. If the signal level is sufficient, the $\overline{\text{TD}}$ input must be low for 20 μs at least once every 32 ms to maintain normal operation. An insufficient signal level indicates the absence of the Receive Carrier; an absence for less than 32 ms will not cause channel establishment to be lost; however, data during this interval will be invalid.

If the signal is present and the level is acceptable at all times, then the threshold input can be low permanently.

Loss of threshold for 51 ms or longer results in a loss of Clear-to-Send. The Transmit Carrier of the originate modem is clamped off and a constant Mark is transmitted from the answer modem.

TIMING DIAGRAMS

FIGURE 4 — ANSWER MODE

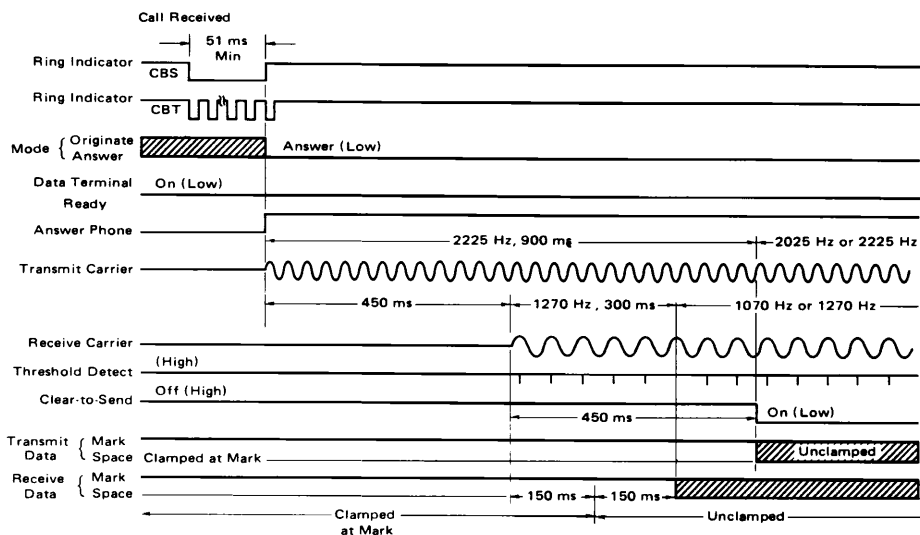


FIGURE 5 — AUTOMATIC DISCONNECT — LONG OR SHORT SPACE

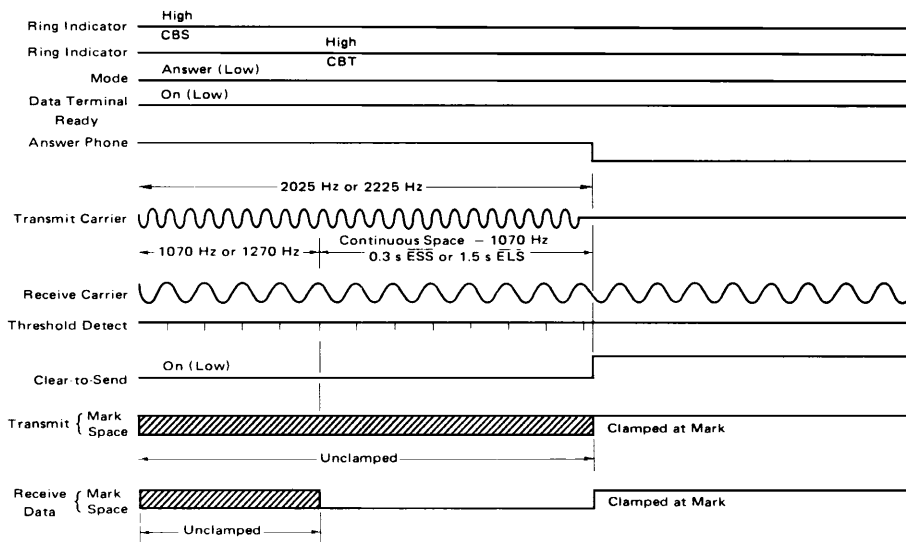


FIGURE 6 — ORIGINATE MODE

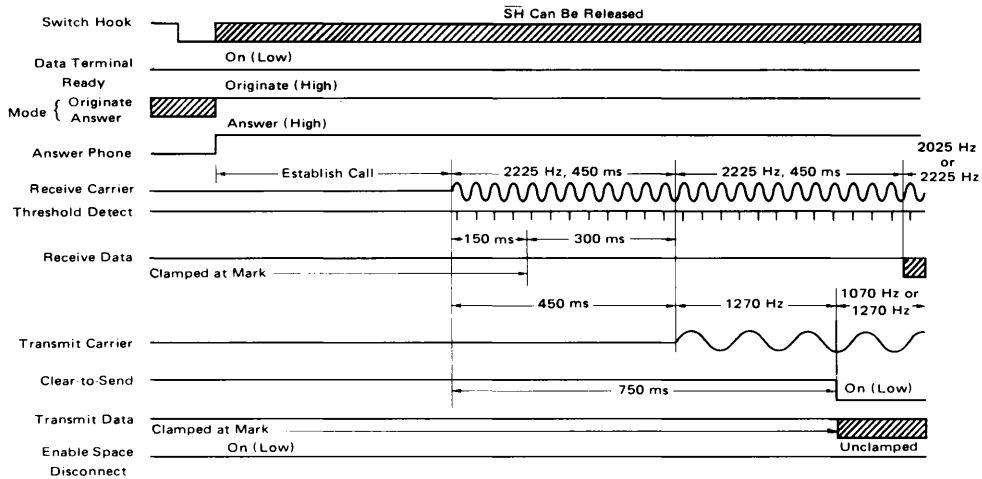
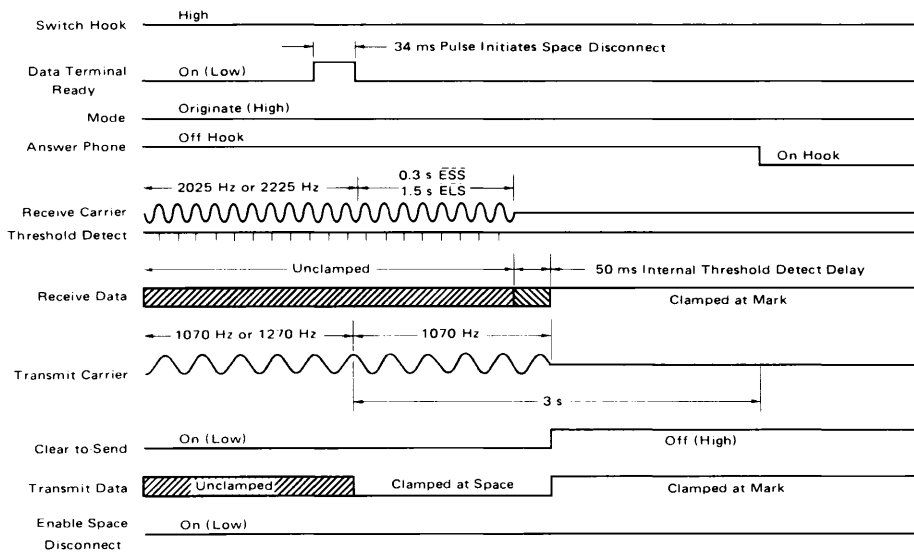


FIGURE 7 — INITIATE DISCONNECT



Receive Data Rate (Rx Rate)

The demodulator has been optimized for signal-to-noise performance at 300 bps and 600 bps. The Receive Data Rate input must be low for 0-600 bps and should be high for 0-300 bps.

Transmit Data (Tx Data)

Transmit Data is the binary information presented to the modem function for modulation with FSK techniques. A high level represents a Mark.

Data Terminal Ready (DTR)

The Data Terminal Ready signal must be low before the modem function will be enabled. To initiate a disconnect, DTR is held high for 34 ms minimum. A disconnect will occur 3 s later.

Break Release (Brk R)

After receiving a 150 ms space signal, the clamped high condition of the Receive Break output can be removed by holding Break Release low for at least 20 μ s.

Transmit Break (Tx Brk)

The Break command is used to signal the remote modem to stop sending data.

A Transmit Break (low) greater than 34 ms forces the modem to send a continuous space signal for 233 ms. Transmit Break must be initiated only after CTS has been established. This is a negative edge sense input. Prior to initiating Tx Brk, this input must be held high for a minimum of 34 ms.

Enabled Space Disconnect (ESD)

When ESD is strapped low and DTR is pulsed to initiate a disconnect, the modem transmits a space for either 3 s or until a loss of threshold is detected, whichever occurs first. If ESD is strapped high, data instead of a space is transmitted. A disconnect occurs at the end of 3 s.

Enable Short Space Disconnect (ESS)

ESS is a strapping option which, when low, will automatically hang up the phone upon receipt of a continuous space for 0.3 s. ESS and ELS must not be simultaneously strapped low.

Enable Long Space Disconnect (ELS)

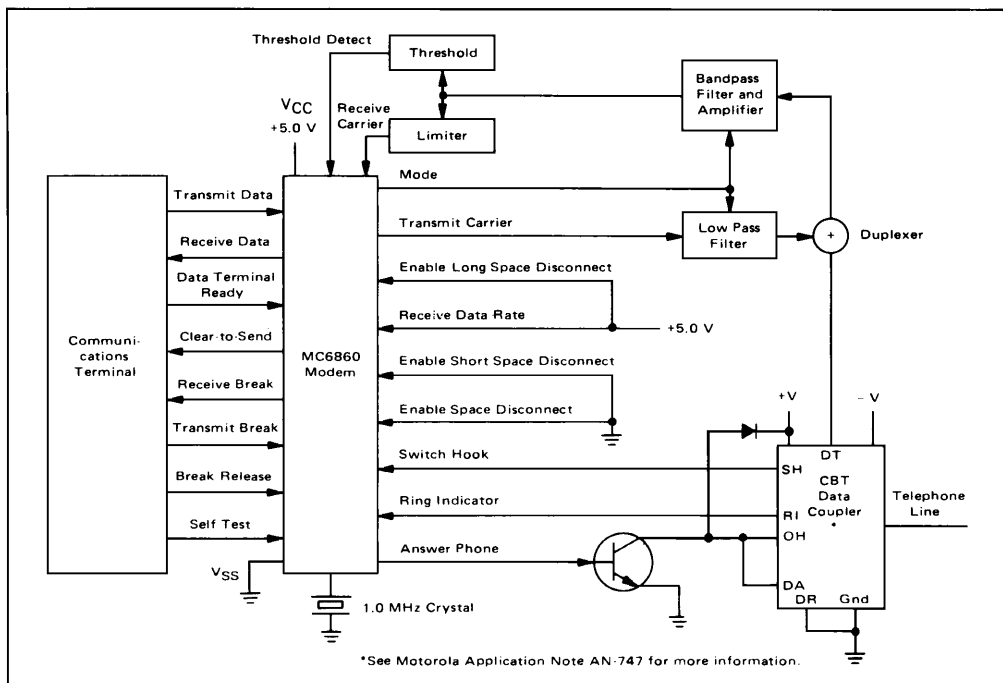
ELS is a strapping option which, when low, will automatically hang up the phone upon receipt of a continuous space for 1.5 s.

Crystal (Xtal)

A 1.0 MHz crystal with the following parameters is required to utilize the on-chip oscillator. A 1.0-MHz square wave can also be fed into this input to satisfy the clock requirement.

Mode:	Parallel
Frequency:	1.0 MHz \pm 0.1%
Series Resistance:	750 ohms max
Shunt Capacitance:	7.0 pF max
Temperature:	0-70°C
Test Level:	1.0 mW
Load Capacitance:	13 pF

**FIGURE 8 — I/O INTERFACE CONNECTIONS FOR MC6860
(ORIGINATE/ANSWER MODEM)**





When utilizing the 1.0 MHz crystal, external parasitic capacitance, including crystal shunt capacitance, must be ≤ 9 pF at the crystal input. Reliable crystal oscillator start-up requires that the V_{CC} power-on transition time be > 15 milliseconds.

Test Clock (TST)

A test signal input is provided to decrease the test time of the chip. In normal operation this input *must be strapped low*.

Self Test (\overline{ST})

When a low voltage level is placed on this input, the demodulator is switched to the modulator frequency and demodulates the transmitted FSK signal. Channel establishment, which occurred during the initial handshake, is not lost during self test. The *Mode Control* output changes state during Self Test, permitting the receive filters to pass the local Transmit Carrier.

\overline{ST}	SH	\overline{RI}	Mode
H		H	H
H	H	L	L
L		H	L
L	H	L	H

*Note maximum SH low time in Table 1.

Answer Phone (An Ph)

Upon receipt of Ring Indicator or Switch Hook signal and Data Terminal Ready, the Answer Phone output goes high $[(SH + RI) \cdot DTR]$. This signal drives the base of a transistor which activates the Off Hook, and Data Transmission control lines in the data coupler. Upon call completion, the Answer Phone signal returns to a low level.

Mode

The Mode output indicates the Answer (low) or Originate (high) status of the modem. This output changes state when a Self Test command is applied.

Clear-To-Send (\overline{CTS})

A low on the \overline{CTS} output indicates the Transmit Data input has been unclamped from a steady Mark, thus allowing data transmission.

Receive Data (Rx Data)

The Receive Data output is the data resulting from demodulating the Receive Carrier. A Mark is a high level.

Receive Break (Rx Brk)

Upon receipt of a continuous 150 ms space, the modem automatically clamps the Receive Break output high. This output is also clamped high until Clear-to-Send is established.

Digital Carrier (FO)

A test signal output is provided to decrease the chip test time. The signal is a square wave at the transmit frequency.

Transmit Carrier (Tx Car)

The Transmit Carrier is a digitally-synthesized sine wave (Figure 9) derived from the 1.0 MHz crystal reference. The frequency characteristics are as follows:

Mode	Data	Transmit Frequency	Tolerance*
Originate	Mark	1270 Hz	-0.15 Hz
Originate	Space	1070 Hz	0.90 Hz
Answer	Mark	2225 Hz	-0.31 Hz
Answer	Space	2025 Hz	-0.71 Hz

*The reference frequency tolerance is not included.

The proper output frequency is transmitted within $3.0 \mu s$ following a data bit change with no more than $2.0 \mu s$ phase discontinuity. The typical output level is 0.35 V (RMS) into 100 k ohm load impedance.

The second harmonic is typically 32 dB below the fundamental (see Figure 10).

POWER-ON RESET

Power-on reset is provided on-chip to insure that when power is first applied the Answer Phone output is in the low (inactive) state. This holds the modem in the inactive or idle mode until a SH or RI signal has been applied. Once power has been applied, a momentary loss of power at a later time may not be of sufficient time to guarantee a chip reset through the power-on reset circuit.

To insure initial power-on reset action, the external parasitic capacitance on RI and SH should be < 30 pF. Capacitance values > 30 pF may require the use of an external pullup resistor to V_{CC} on these inputs in addition to the pullup devices already provided on chip.

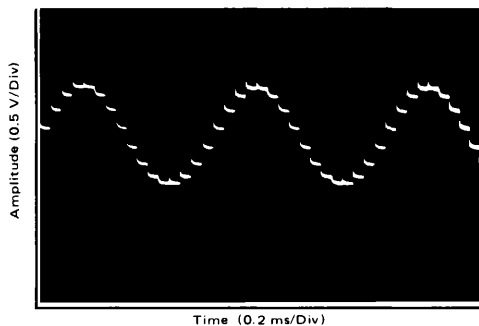


FIGURE 9 — TRANSMIT CARRIER SINE WAVE

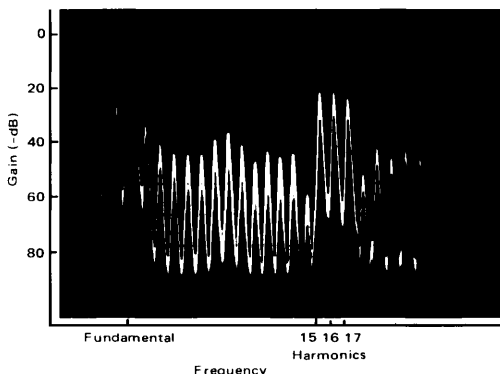
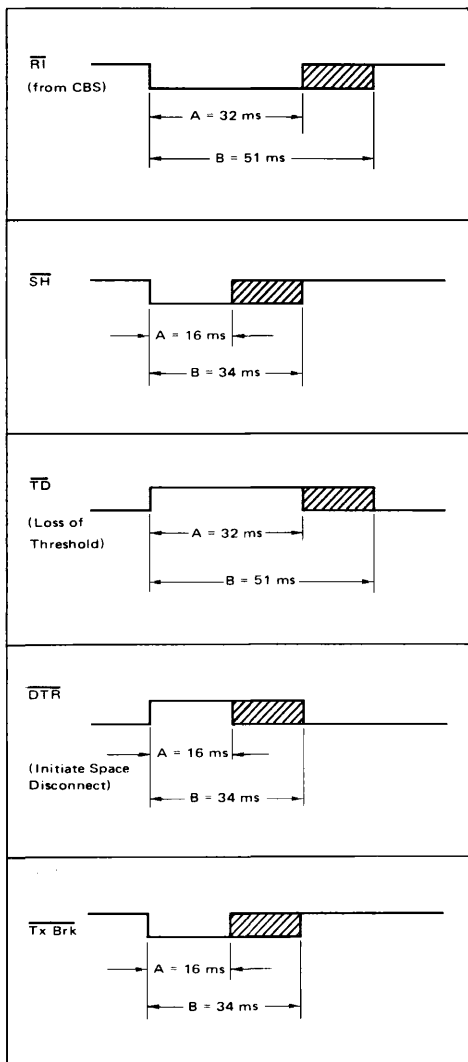


FIGURE 10 — TRANSMIT CARRIER FREQUENCY SPECTRUM

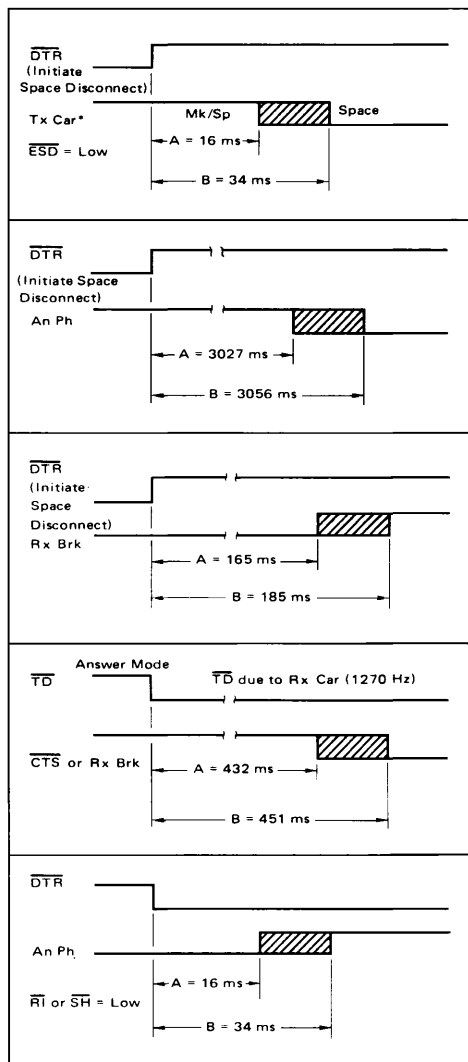
TABLE 1 – ASYNCHRONOUS INPUT PULSE WIDTH AND OUTPUT DELAY VARIATIONS
(Time delays specified do not include the 1-MHz reference tolerance.)

Due to the asynchronous nature of the input signals with respect to the circuit internal clock, a delay variation or input pulse width requirement will exist. Time delay A is the maximum time for which no response will occur. Time delay B is the minimum time required to guarantee an input response. Input signal widths in the cross-hatched region (i.e., greater than A but less than B) may or may not be recognized as valid.

For output delays, time A is the minimum delay before an output will respond. Time B is the maximum delay for an output to respond. Output signal response may or may not occur in the cross-hatched region (i.e., greater than A but less than B).

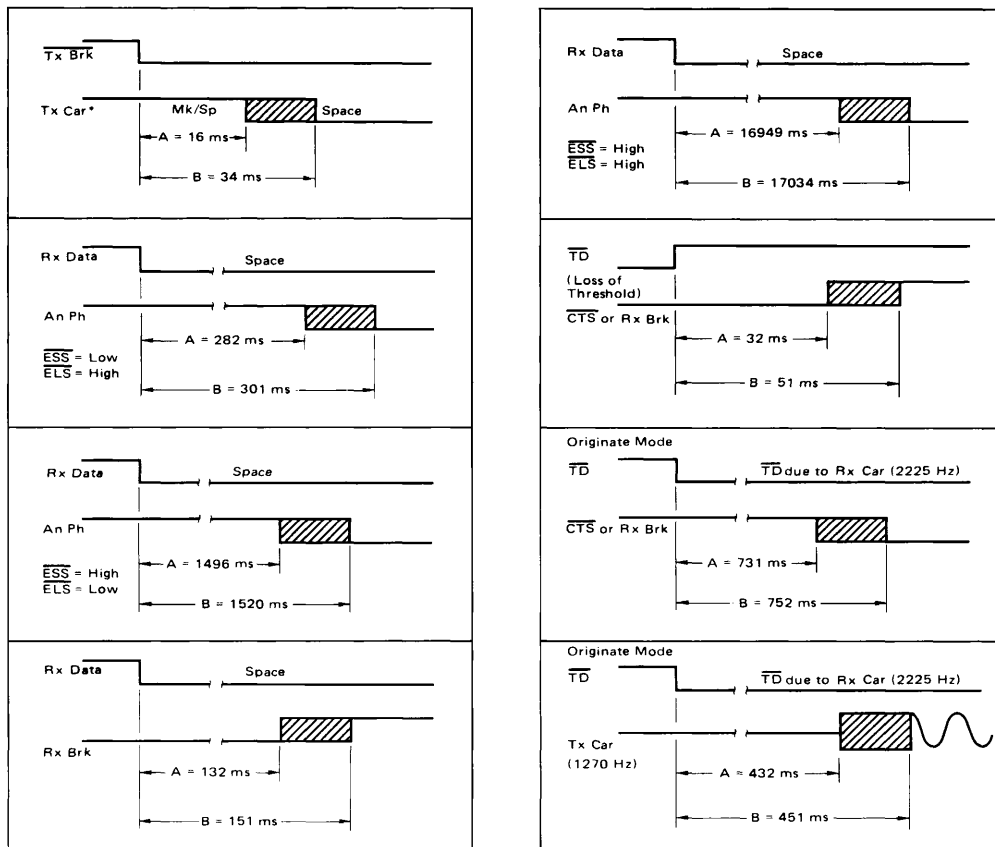
INPUT PULSES

* Digital Representation.

OUTPUT DELAYS

(continued)

TABLE 1 – OUTPUT DELAY VARIATIONS (continued)



* Digital Representation

TABLE 2 – TRANSMIT BREAK AND DISCONNECT DELAYS

Function Description	Min	Max	Unit
Tx Brk (Space Duration)	232	235	ms
Space Disconnect (Space Duration) (DTR = High, ESD and TD = Low)	3010	3023	ms
Loss of Carrier Disconnect (Measured from positive edge of CTS to negative edge of An Ph, with RT, SH, and TD = High)	16965	17034	ms
Override Disconnect (Measured from positive edge of RT or SH to negative edge of An Ph, with TD = High)	16916	17101	ms

FIGURE 11 — FLOW DIAGRAM

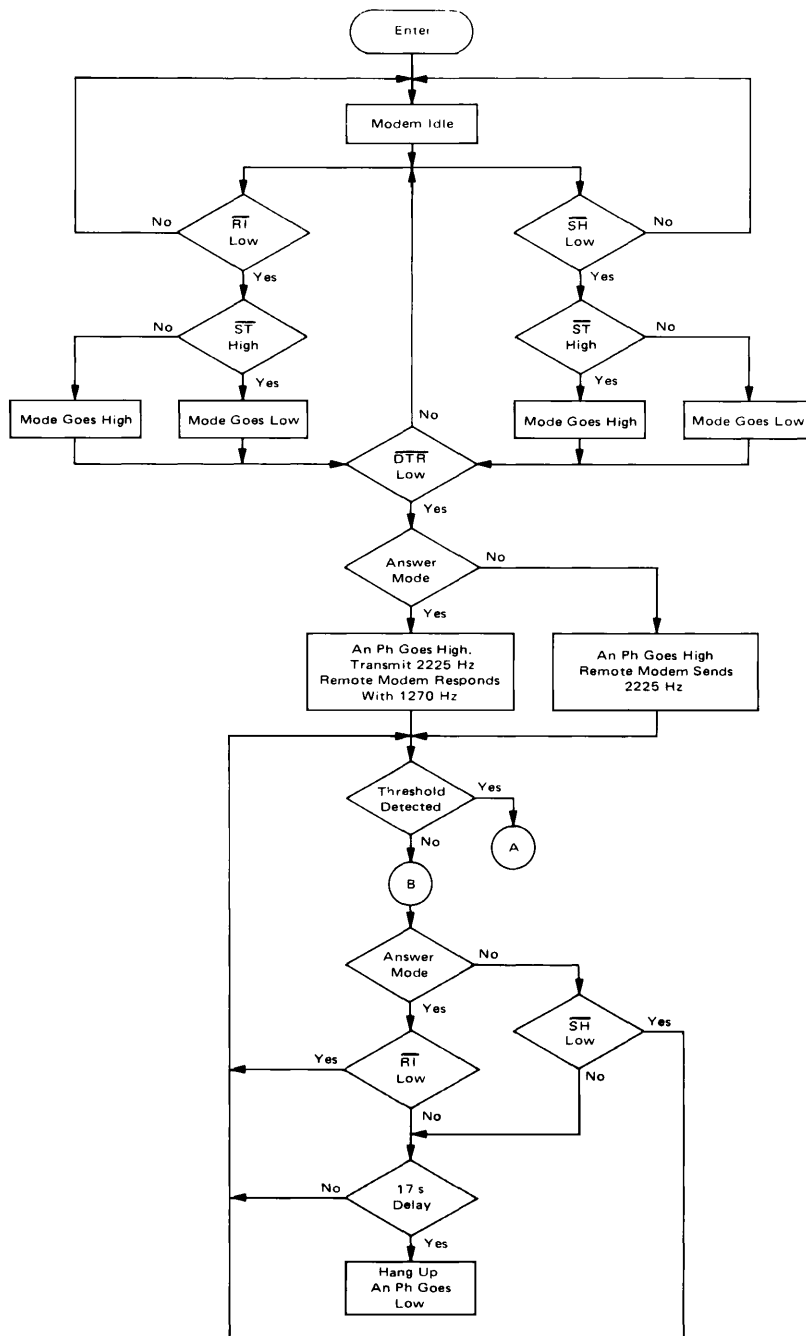
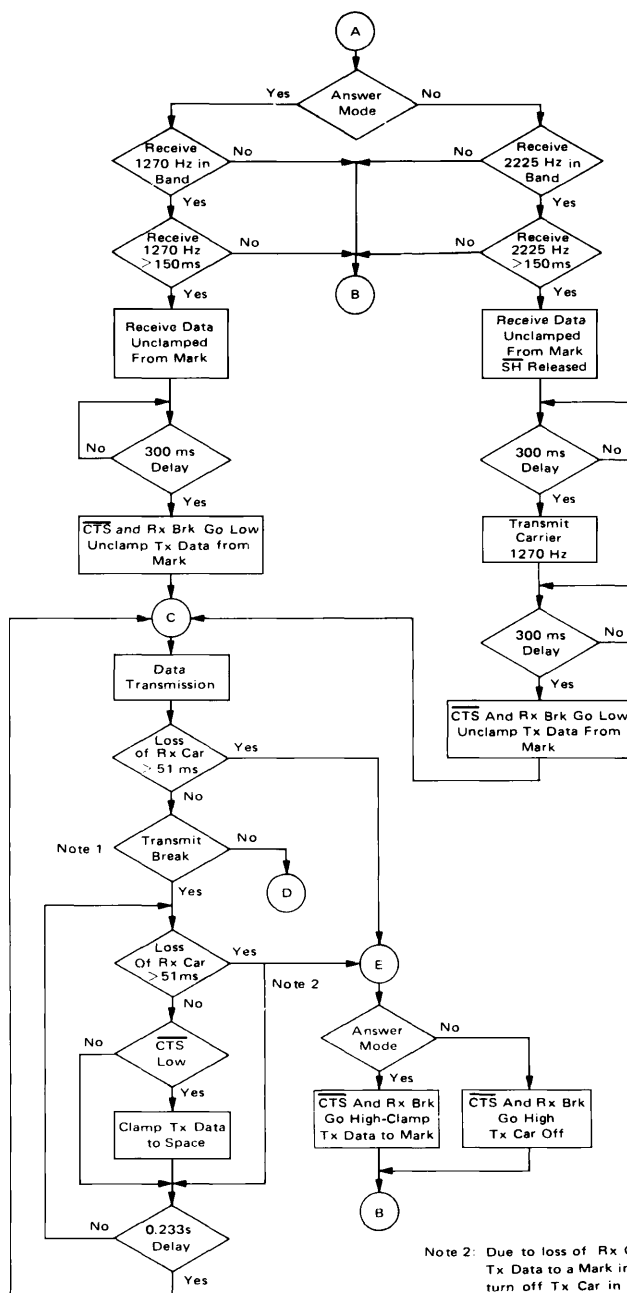


FIGURE 11 — FLOW DIAGRAM (CONTINUED)

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Note 1: Transmit Break, Initiate Space Disconnect, and Receive Space are mutually exclusive events.

Note 2: Due to loss of Rx Car, the modem will clamp Tx Data to a Mark in the Answer Mode and will turn off Tx Car in the Originate Mode. If Rx Car is detected before completion of Tx Brk or Initiate Space Disconnect, normal operation of Tx Brk or Initiate Space Disconnect will continue until completion of their respective time delays.

FIGURE 11 — FLOW DIAGRAM (CONCLUDED)

