MOTOROLA
Semiconductors
BOX 20912 • PHOENIX, ARIZONA 85036

MC6860L

Advance Information

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.

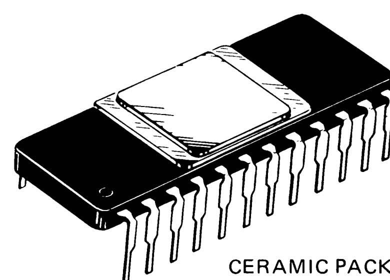
The modem is compatible with the M6800 microcomputer family, interfacing directly with the Asynchronous Communications Interface Adapter to provide low-speed data communications capability.

- 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

MOS

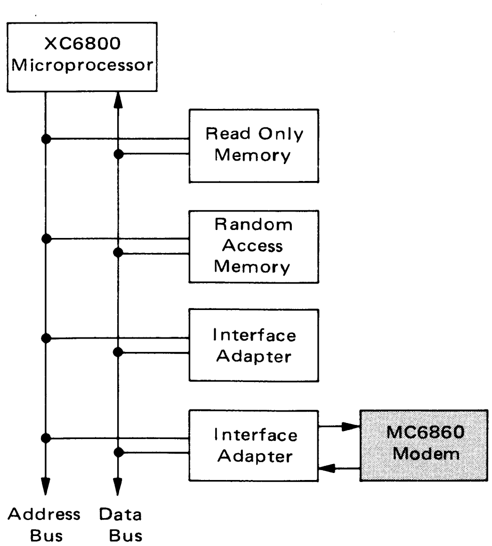
(N-CHANNEL, SILICON-GATE)

0-600 bps
DIGITAL MODEM

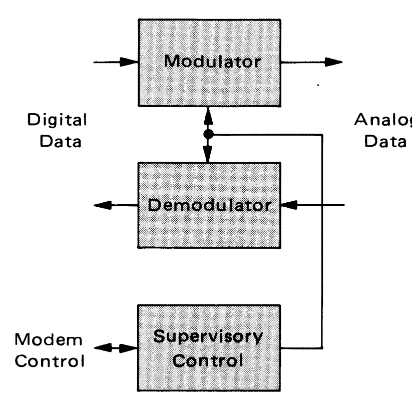


CERAMIC PACKAGE
CASE 684

M6800 MICROCOMPUTER FAMILY
BLOCK DIAGRAM



MC6860 DIGITAL MODEM
BLOCK DIAGRAM



This is advance information and specifications are subject to change without notice.

MAXIMUM RATINGS (Voltages referenced to V_{SS}, Pin 1)

Rating	Symbol	Value	Unit
Supply Voltage	V_{DD}	-0.3 to +7.0	Vdc
Data Input Voltage	V_{in}	-0.3 to +7.0	Vdc
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.

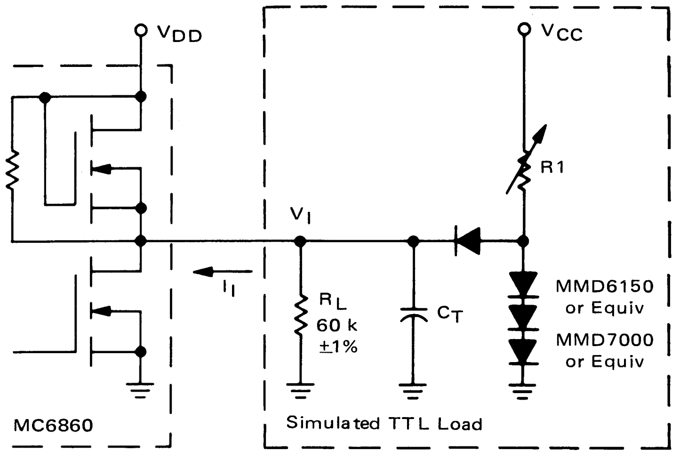
ELECTRICAL CHARACTERISTICS (V_{DD} = 5.0 ±0.25 Vdc, all voltages referenced to V_{SS} = 0, T_A = 0 to 70°C, all outputs loaded as shown in Figure 1 unless otherwise noted.)

Characteristic	Symbol	Min	Typ	Max	Unit
Input High Voltage, All Inputs Except Crystal	V_{IH}	2.0	–	V_{DD}	Vdc
Input Low Voltage, All Inputs Except Crystal	V_{IL}	V_{SS}	–	0.80	Vdc
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, $\overline{TD}$, TST, $\overline{RI}$, $\overline{SH}$	I_{in}	–	–	-0.2	mAdc
$\overline{RI}$, $\overline{SH}$ Inputs		–	–	-1.6	
Input Leakage Current (V_{in} = 7.0 Vdc, V_{DD} = V_{SS}, T_A = 25°C)	I_{IL}	–	–	1.0	µAdc
Output High Voltage, All Outputs Except An Ph and Tx Car (I_{OH1} = -0.04 mAdc, Load A)	V_{OH1}	2.4	–	V_{DD}	Vdc
Output Low Voltage, All Outputs Except An Ph and Tx Car (I_{OL1} = 1.6 mAdc, Load A)	V_{OL1}	V_{SS}	–	0.40	Vdc
Output High Current, An Ph (V_{OH2} = 0.8 Vdc, Load B)	I_{OH2}	0.30	–	–	mAdc
Output Low Voltage, An Ph (I_{OL2} = 0, Load B)	V_{OL2}	V_{SS}	–	0.30	Vdc
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 Mode)	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
V_{DD} Supply Current (All Inputs at V_{SS} and All Outputs Open)	I_{DD}	–	30	65	mAdc

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

FIGURE 1 – OUTPUT TEST LOADS

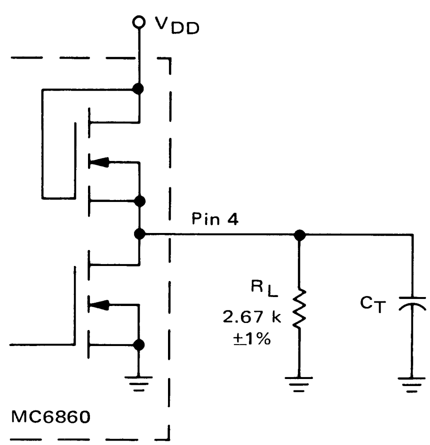
Load A – TTL Output Load for Receive Break, Digital Carrier, Mode, Clear-to-Send, and Receive Data Outputs



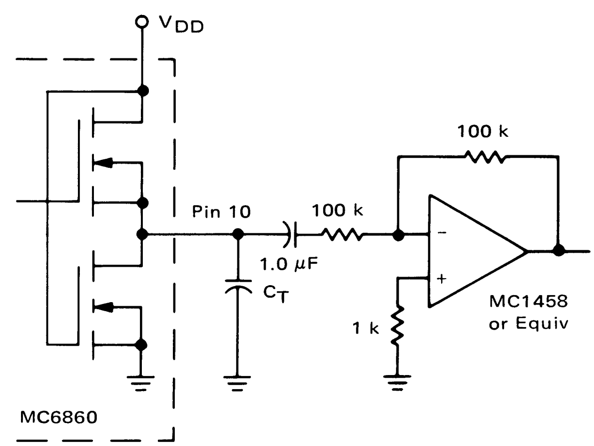
C_T = 20 pF = total parasitic capacitance, which includes probe, wiring, and load capacitances

R1 is adjusted for I_I = 1.6 mA at V_I = 0.4 V when output node is disconnected.

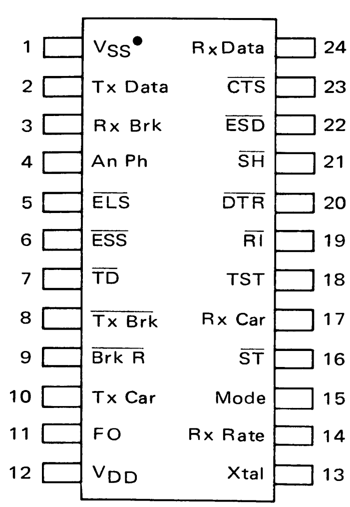
Load B – Answer Phone Load



Load C – Transmit Carrier Load

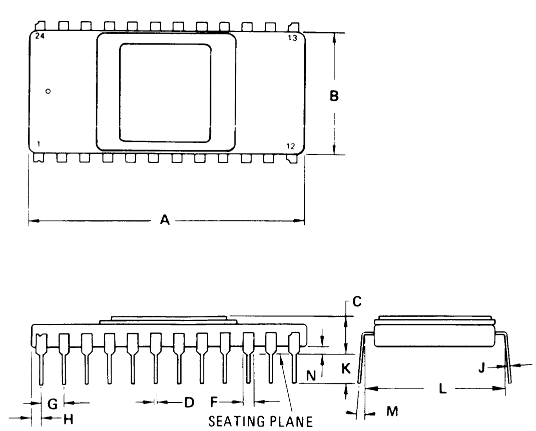


PIN ASSIGNMENT



PACKAGE DIMENSIONS

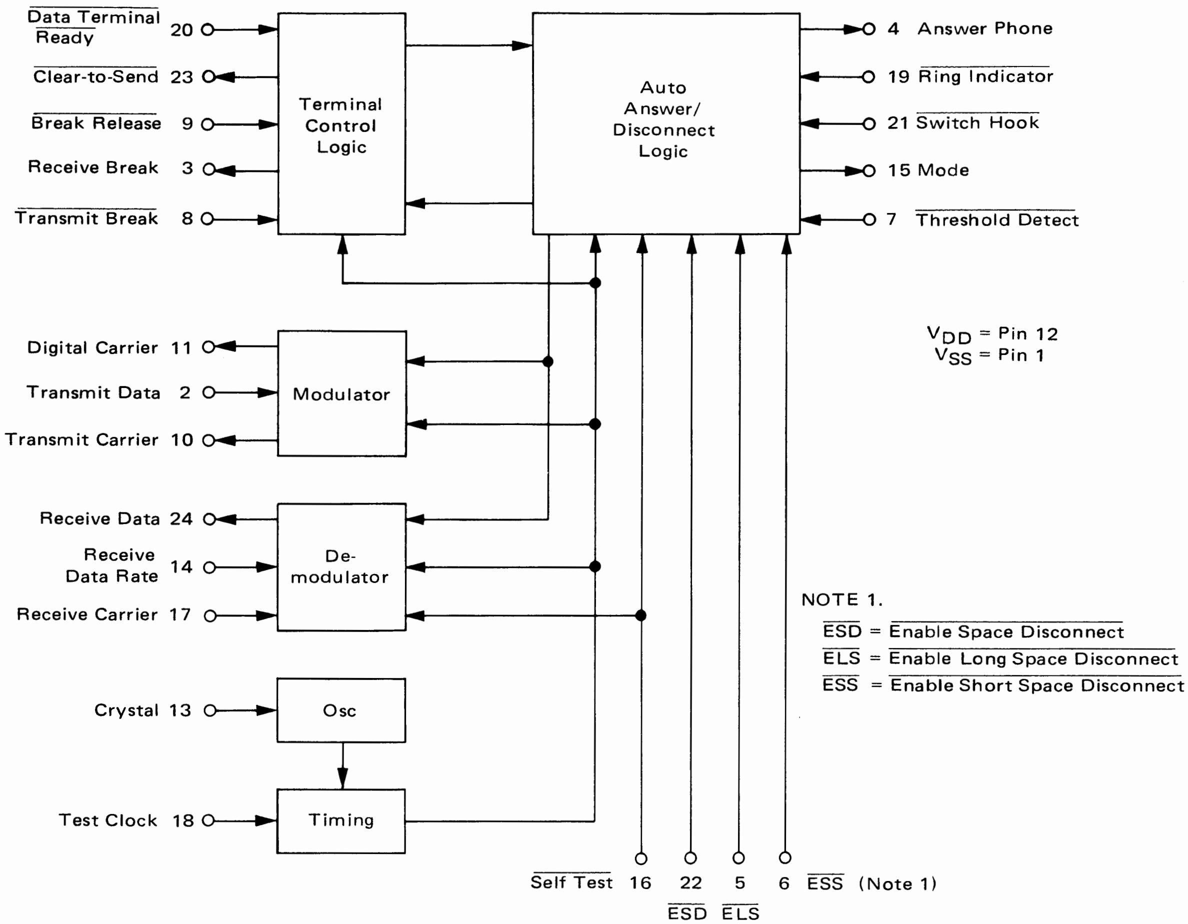
CASE 684-04



DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	29.34	30.86	1.155	1.215
B	12.70	14.22	0.500	0.560
C	3.05	3.94	0.120	0.155
D	0.38	0.51	0.015	0.020
F	0.89	1.40	0.035	0.055
G	2.54 BSC		0.100 BSC	
H	0.89	1.40	0.035	0.055
J	0.20	0.30	0.008	0.012
K	2.92	3.68	0.115	0.145
L	14.86	15.87	0.585	0.625
M	–	15°	–	15°
N	0.51	1.14	0.020	0.045

NOTES:
1. LEADS WITHIN 0.13 mm (0.005) RADIUS OF TRUE POSITION AT SEATING PLANE WITH MAXIMUM MATERIAL CONDITION.
2. LEAD NO. 1 CUT FOR IDENTIFICATION, OR BUMP ON TOP.
3. DIM "L" TO INSIDE OF LEADS. (MEASURED 0.51 mm (0.020) BELOW PKG BASE)

BLOCK DIAGRAM



DEVICE OPERATION*

GENERAL

Figure 2 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. 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. However, if the modem is a stand-alone unit the computer-modem I/O interface must conform to the EIA specification. The use of MC1488 and MC1489A line drivers and receivers will provide the required interface.

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 the Off Hook (OH) and

*See Tables 1 and 2 for delay time tolerances.

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 $\overline{\text{Clear-to-Send}}$ output goes low 450 ms after the receipt of carrier and data presented to the answer modem is transmitted.

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 $\overline{\text{Break Release}}$ command is issued at the receiving station. Upon receipt of a 0.3 s space, with $\overline{\text{Enable Short Space Disconnect}}$ at the most negative voltage (low), the modem automatically hangs up. If $\overline{\text{Enable Long Space Disconnect}}$ is low, the modem requires 1.5 s of continuous space to hang up.

Originate Mode

Upon receipt of a $\overline{\text{Switch Hook}}$ ($\overline{\text{SH}}$) command the modem function is placed in the Originate Mode. If the $\overline{\text{Data Terminal Ready}}$ 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 ±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 $\overline{\text{Clear-to-Send}}$ output is taken low and data can now be transmitted as well as received.

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 $\overline{\text{Data Terminal Ready}}$ into a high state for greater than

FIGURE 2 – TYPICAL MC6860 SYSTEM CONFIGURATION

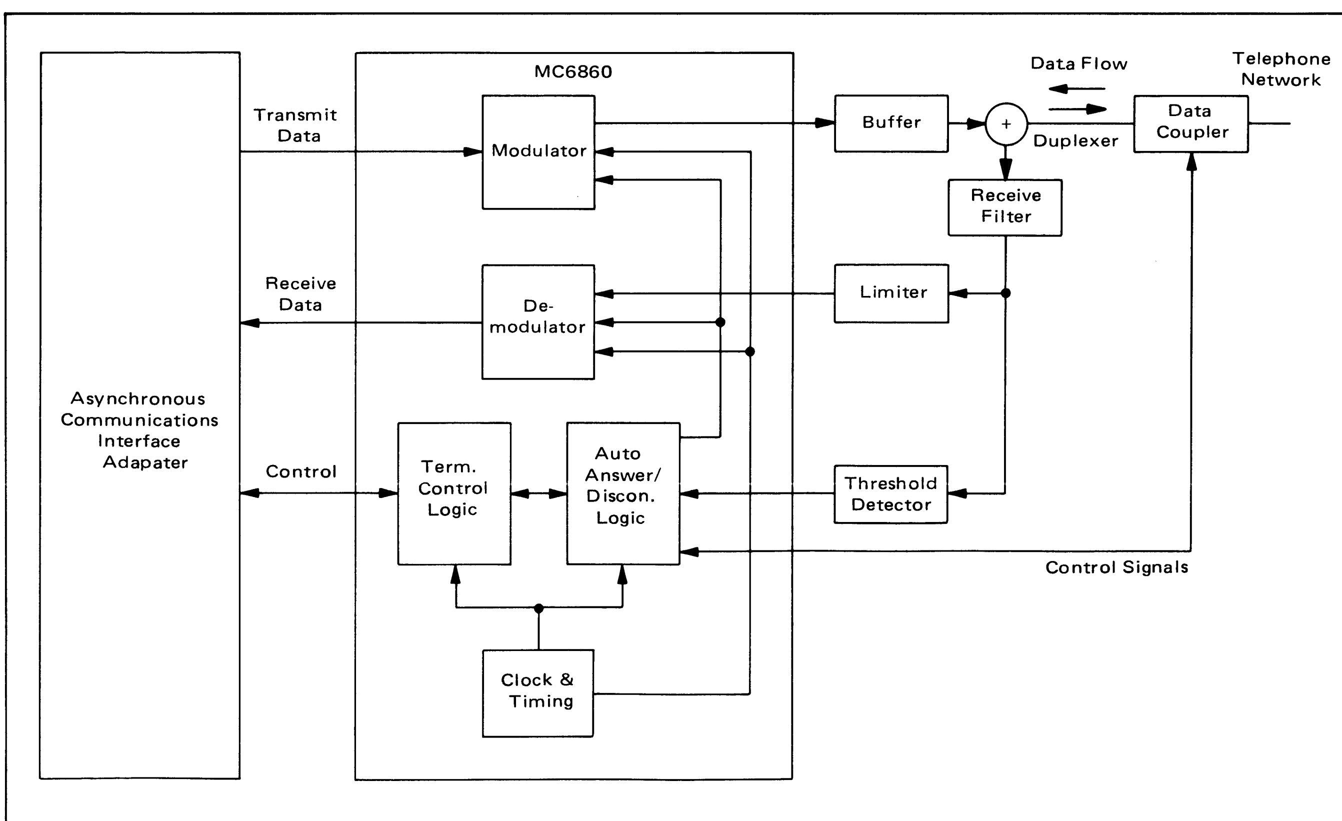
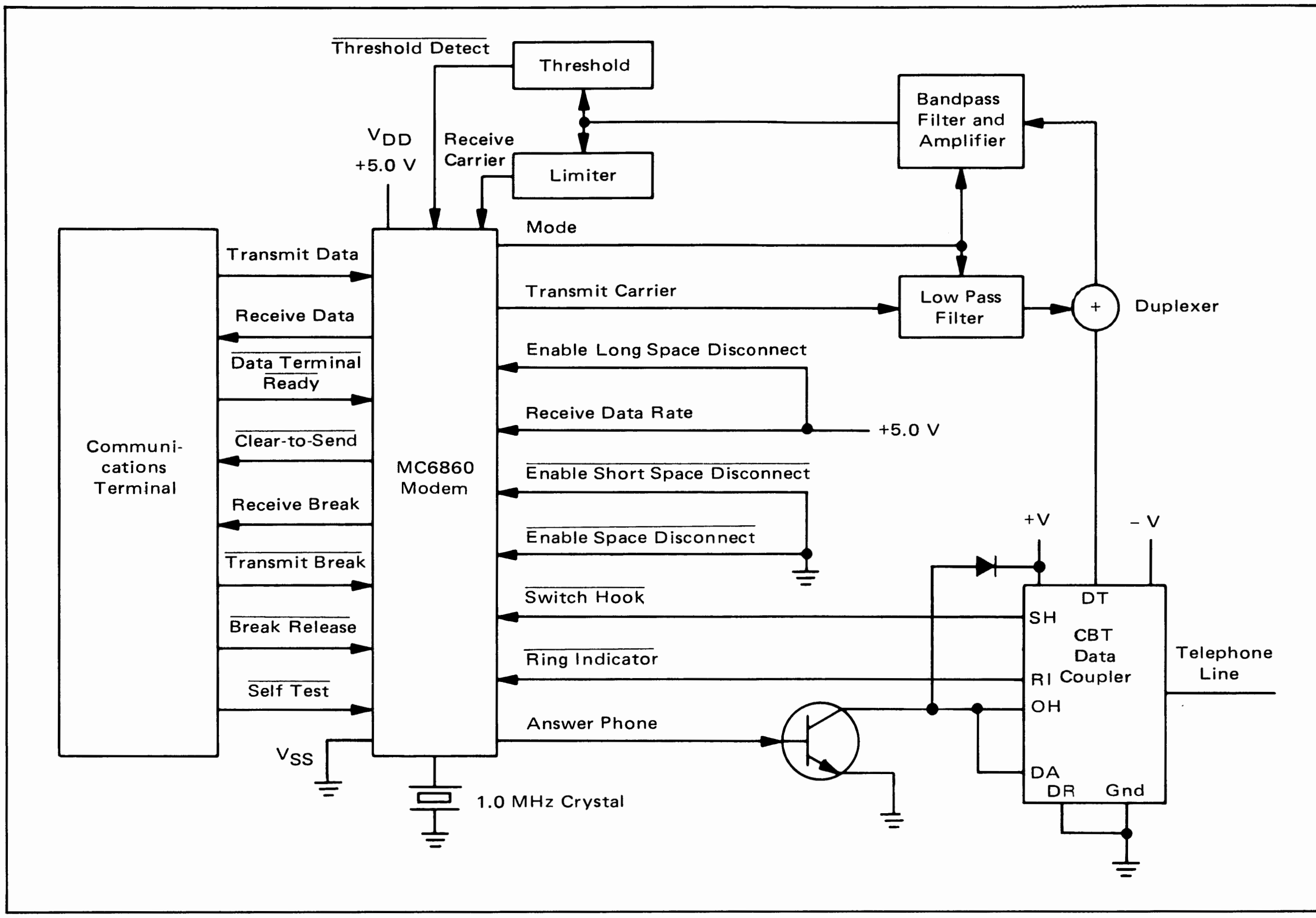


FIGURE 3 — I/O INTERFACE CONNECTIONS FOR MC6860
(ORIGINATE/ANSWER MODEM)



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 ESD is high the modem will transmit data until hang-up occurs 3 s later. Transmit Break is clamped 150 ms following the Data Terminal Ready interrupt.

INPUT/OUTPUT FUNCTIONS

Figure 3 shows the I/O interface for the low speed modem. The following is a description of each individual signal:

Receive Carrier (Rx Car)

The Receive Carrier is the FSK input to the demodulator. The local Transmit Carrier must be balanced or filtered out prior to this input, leaving only the Receive Carrier in the signal. The Receive Carrier must also be hard limited. Any half-cycle period greater than or equal to 429 ± 1.0 μs for the low band or 235 ± 1.0 μs for the high band is detected as a space.

Ring Indicator (RI)

The modem function will recognize the receipt of a call from the CBT if at least 20 cycles of the 20-47 Hz ringing signal (low level ⩾ 50% of the duty cycle) are present. The CBS 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 is recognized if the RI signal is present for at least 51 ms. This input is held high except during ringing. A RI signal automatically places the modem function in the Answer Mode.

Switch Hook (SH)

SH interfaces directly with the CBT and via the EIA RS-232 level conversion for the CBS. An SH signal automatically places the modem function in the Originate Mode.

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

Threshold Detect (TD)

This input is derived from an external threshold detector. If the signal level is sufficient, the 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 $\overline{\text{Clear-to-Send}}$. The Transmit Carrier of the originate modem is clamped off and a constant Mark is transmitted from the answer modem.

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.

$\overline{\text{Data Terminal Ready}}$ ($\overline{\text{DTR}}$)

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

$\overline{\text{Break Release}}$ ($\overline{\text{Brk R}}$)

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 μs.

$\overline{\text{Transmit Break}}$ ($\overline{\text{Tx Brk}}$)

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

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

$\overline{\text{Enabled Space Disconnect}}$ ($\overline{\text{ESD}}$)

When $\overline{\text{ESD}}$ is strapped low and $\overline{\text{DTR}}$ 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 $\overline{\text{ESD}}$ is strapped high, data instead of a space is transmitted. A disconnect occurs at the end of 3 s.

$\overline{\text{Enable Short Space Disconnect}}$ ($\overline{\text{ESS}}$)

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

$\overline{\text{Enable Long Space Disconnect}}$ ($\overline{\text{ELS}}$)

$\overline{\text{ELS}}$ 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 ±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

When utilizing the 1.0-MHz crystal, external parasitic capacitance, including crystal shunt capacitance, must be ⩽9 pF at the crystal input.

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.*

$\overline{\text{Self Test}}$ ($\overline{\text{ST}}$)

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 $\overline{\text{Self Test}}$, permitting the receive filters to pass the local Transmit Carrier.

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

Answer Phone (An Ph)

Upon receipt of $\overline{\text{Ring Indicator}}$ or $\overline{\text{Switch Hook}}$ signal and $\overline{\text{Data Terminal Ready}}$, the Answer Phone output goes high [($\overline{\text{SH}}$ + $\overline{\text{RI}}$) • $\overline{\text{DTR}}$]. 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 $\overline{\text{Self Test}}$ command is applied.

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

A low on the $\overline{\text{CTS}}$ 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 $\overline{\text{Clear-to-Send}}$ 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 4) 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	0.09 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 μs following a data bit change with no more than 2.0 μs phase discontinuity. The typical output level is 0.35 V (RMS) into a 100 k-ohm load impedance.

The second harmonic is typically 32 dB below the fundamental (Figure 5).

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 $\overline{\text{SH}}$ or $\overline{\text{RI}}$ 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 $\overline{\text{RI}}$ and $\overline{\text{SH}}$ should be < 30 pF. Capacitance values > 30 pF may require the use of an external pullup resistor to V_{DD} on these inputs in addition to the pullup devices already provided on chip.

FIGURE 4 — TRANSMIT CARRIER SINE WAVE

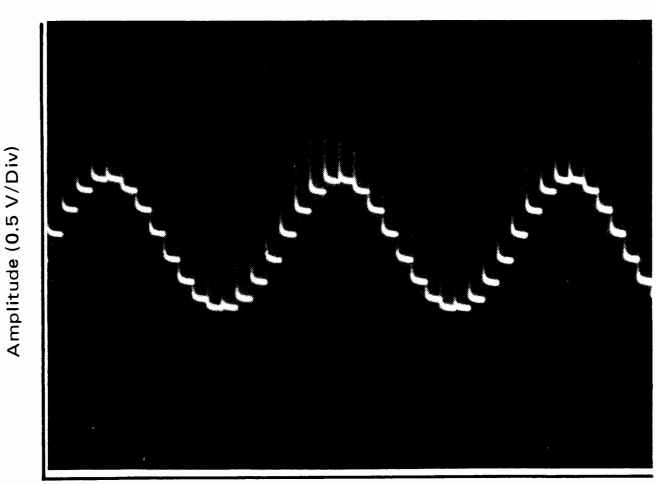
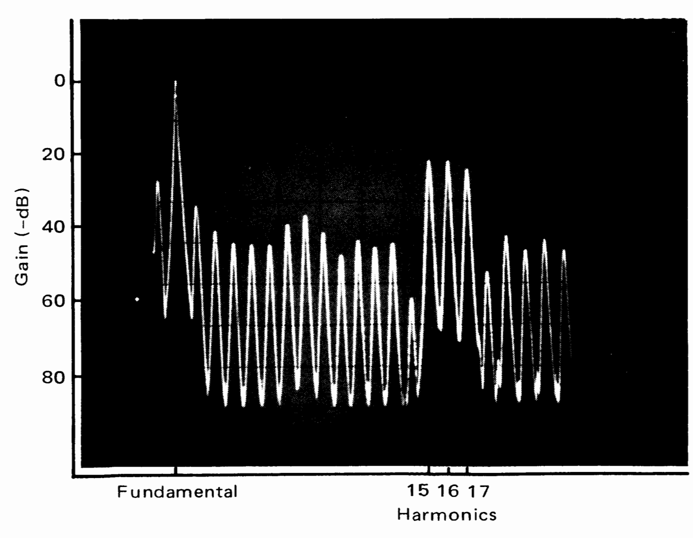


FIGURE 5 — TRANSMIT CARRIER FREQUENCY SPECTRUM



TIMING DIAGRAMS

FIGURE 6 – ANSWER MODE

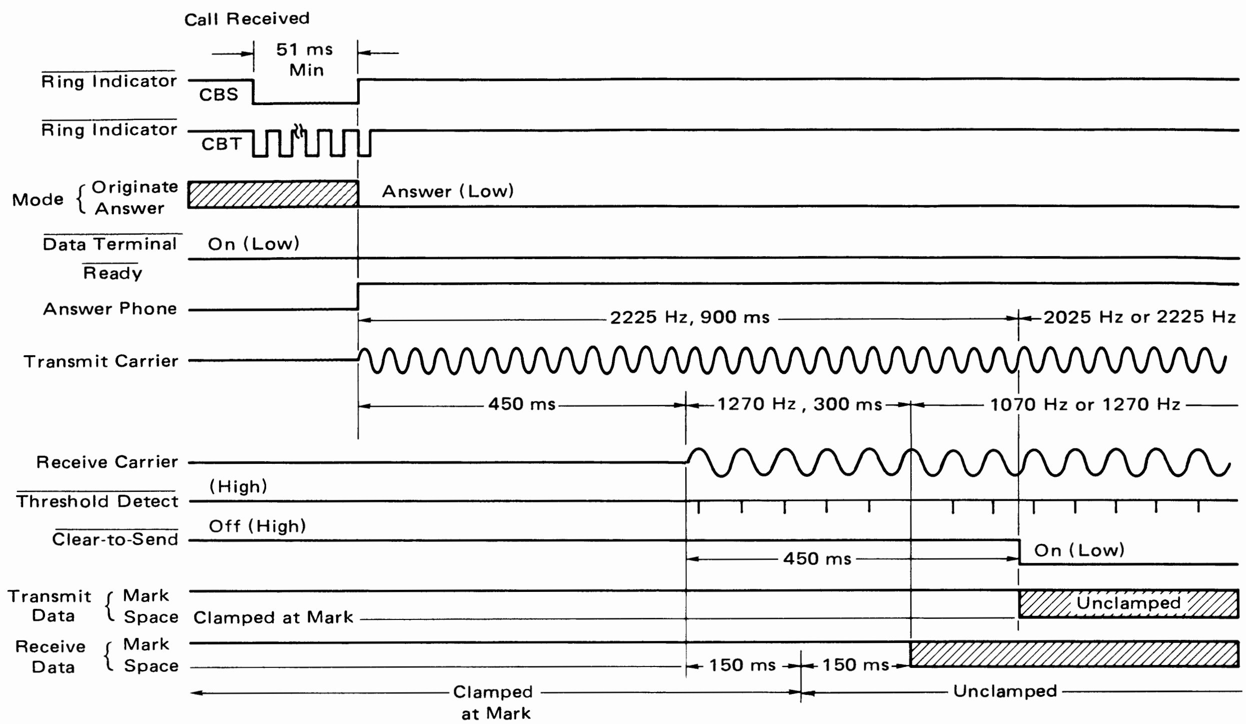


FIGURE 7 – AUTOMATIC DISCONNECT – LONG OR SHORT SPACE

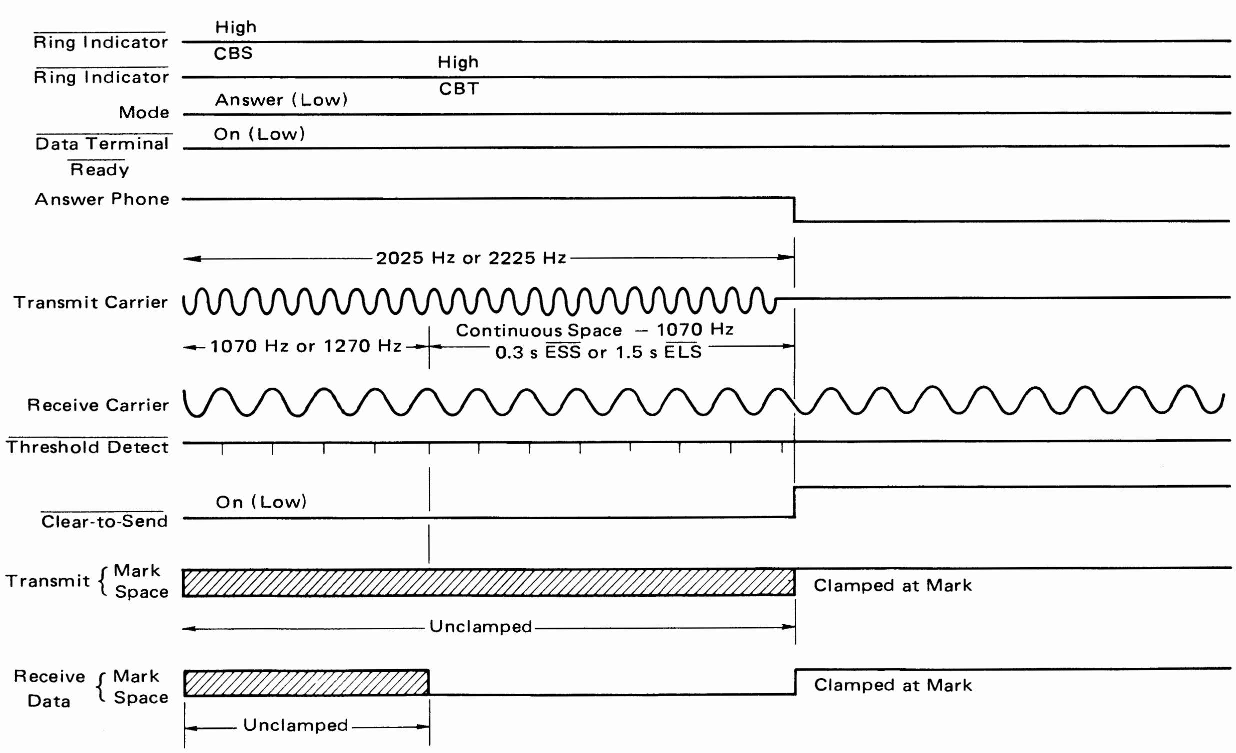


FIGURE 8 – ORIGINATE MODE

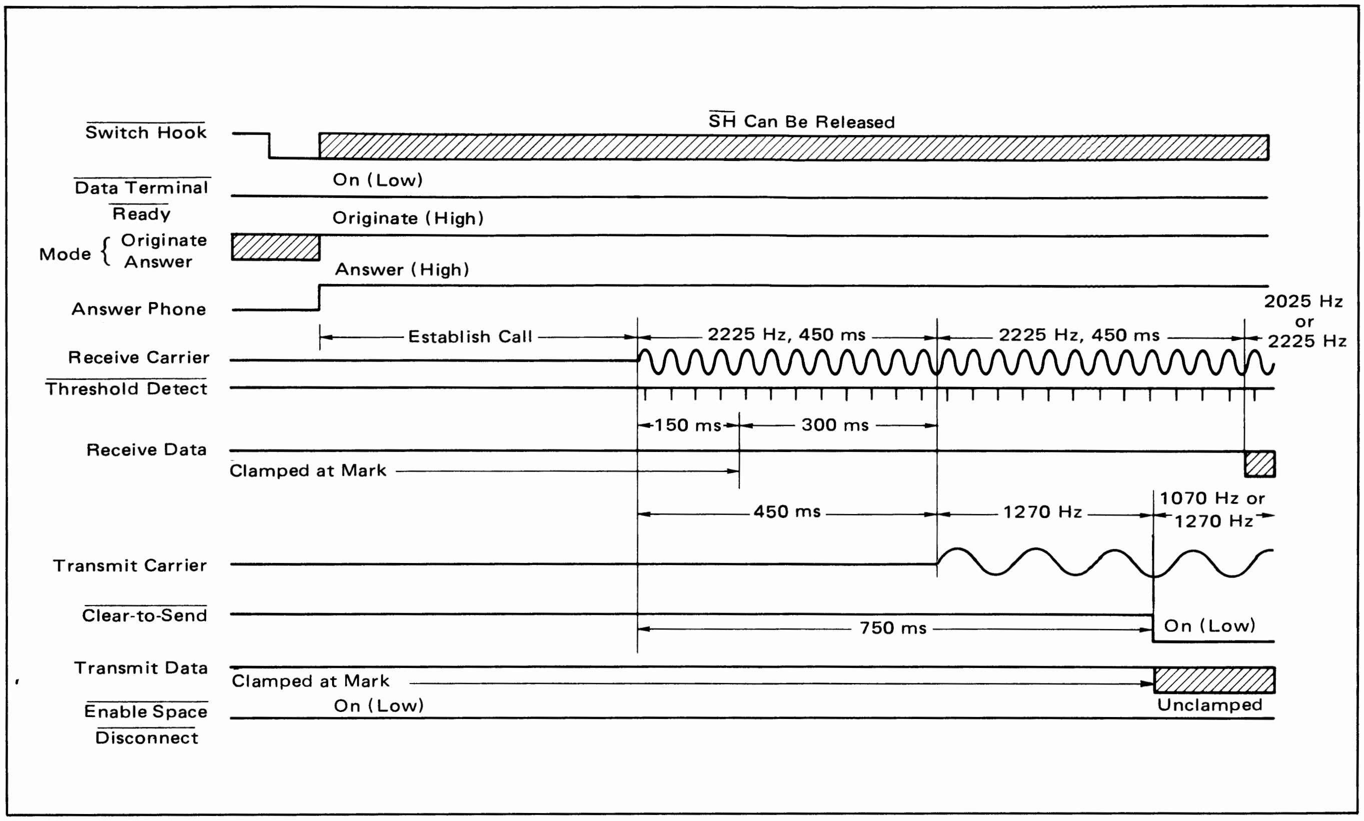


FIGURE 9 – INITIATE DISCONNECT

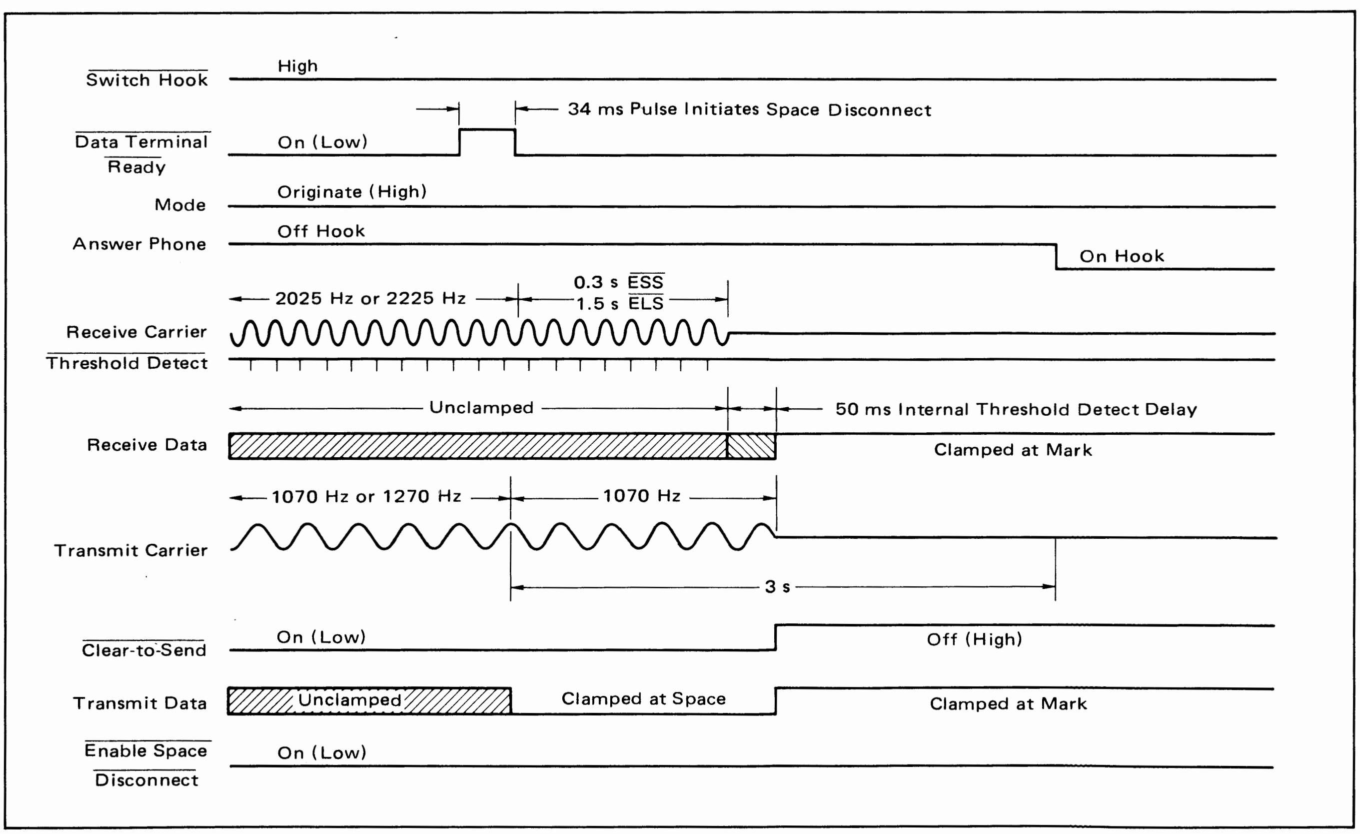


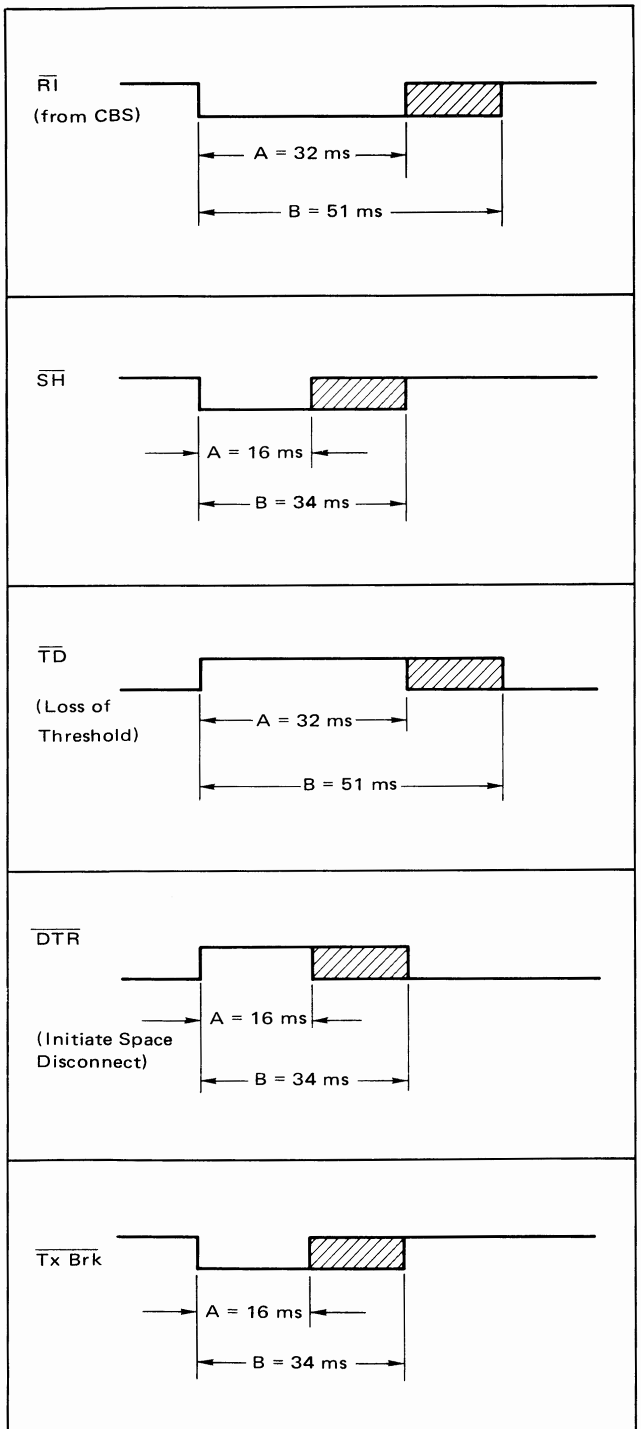
TABLE 1 – ASYNCHRONOUS INPUT PULSE WIDTH AND OUTPUT DELAY VARIATIONS

(Time delays specified do not include the 1-MHz reference tolerance.)

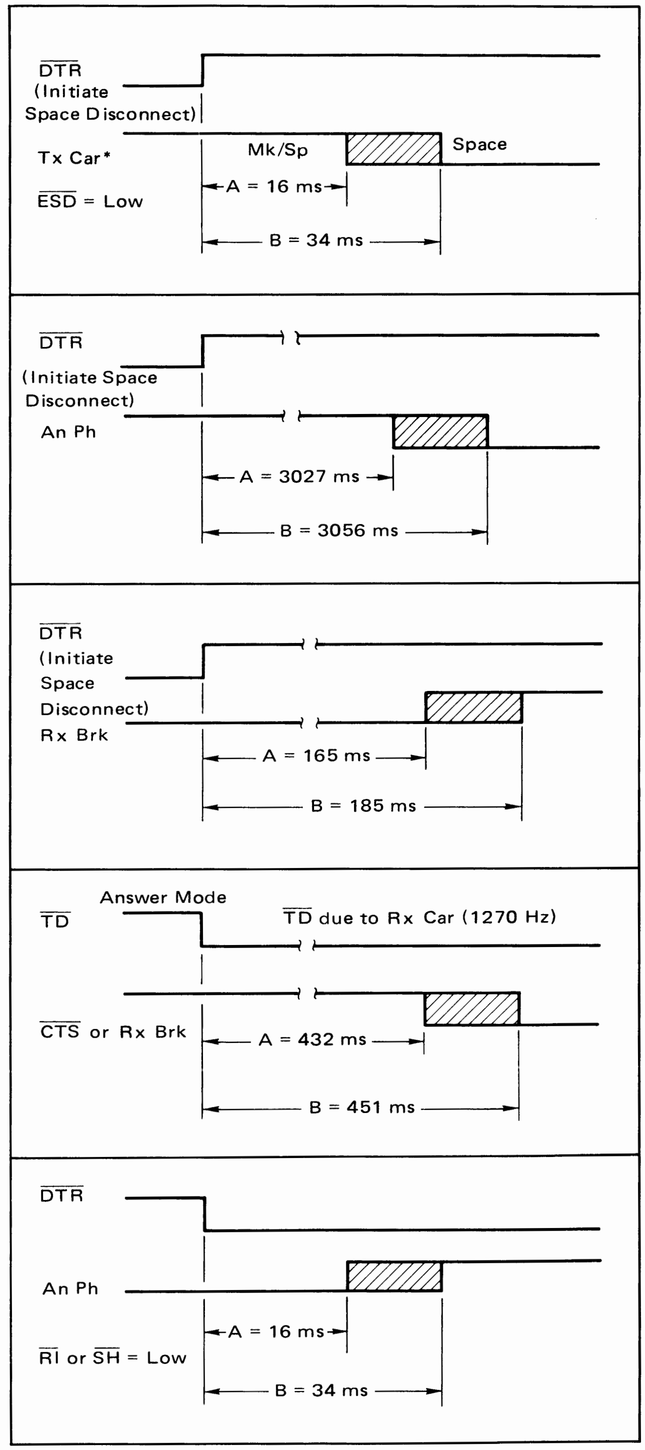
Due to the asynchronous nature of the input signals with respect to the circuit internal clock, a delay variation or input pulse width requirement will exist. Time delay A is the maximum time for which no response will occur. Time delay B is the minimum time required to guarantee an input response. Input 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



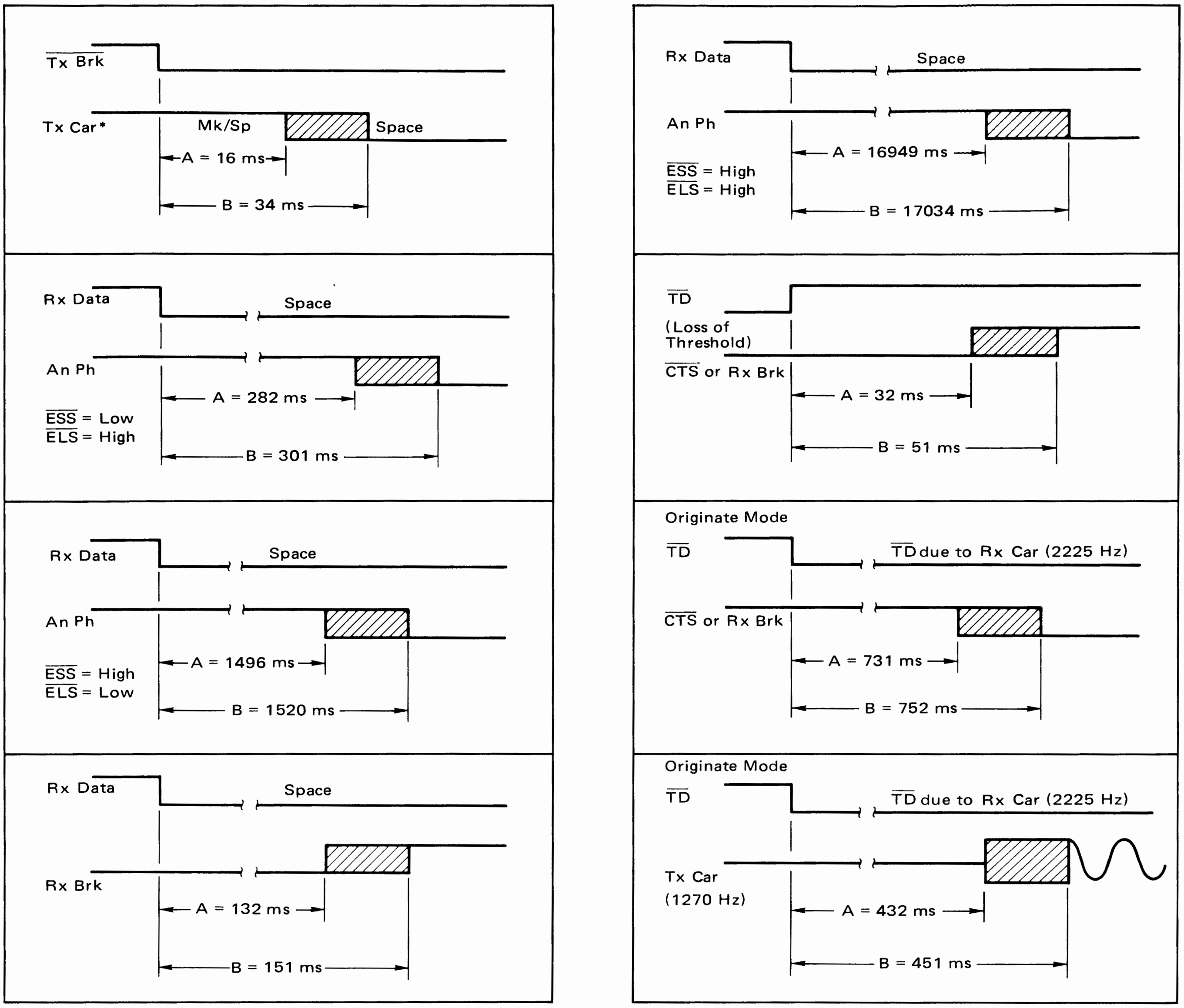
OUTPUT DELAYS



*Digital Representation.

(continued)

TABLE 1 – OUTPUT DELAY VARIATIONS (continued)

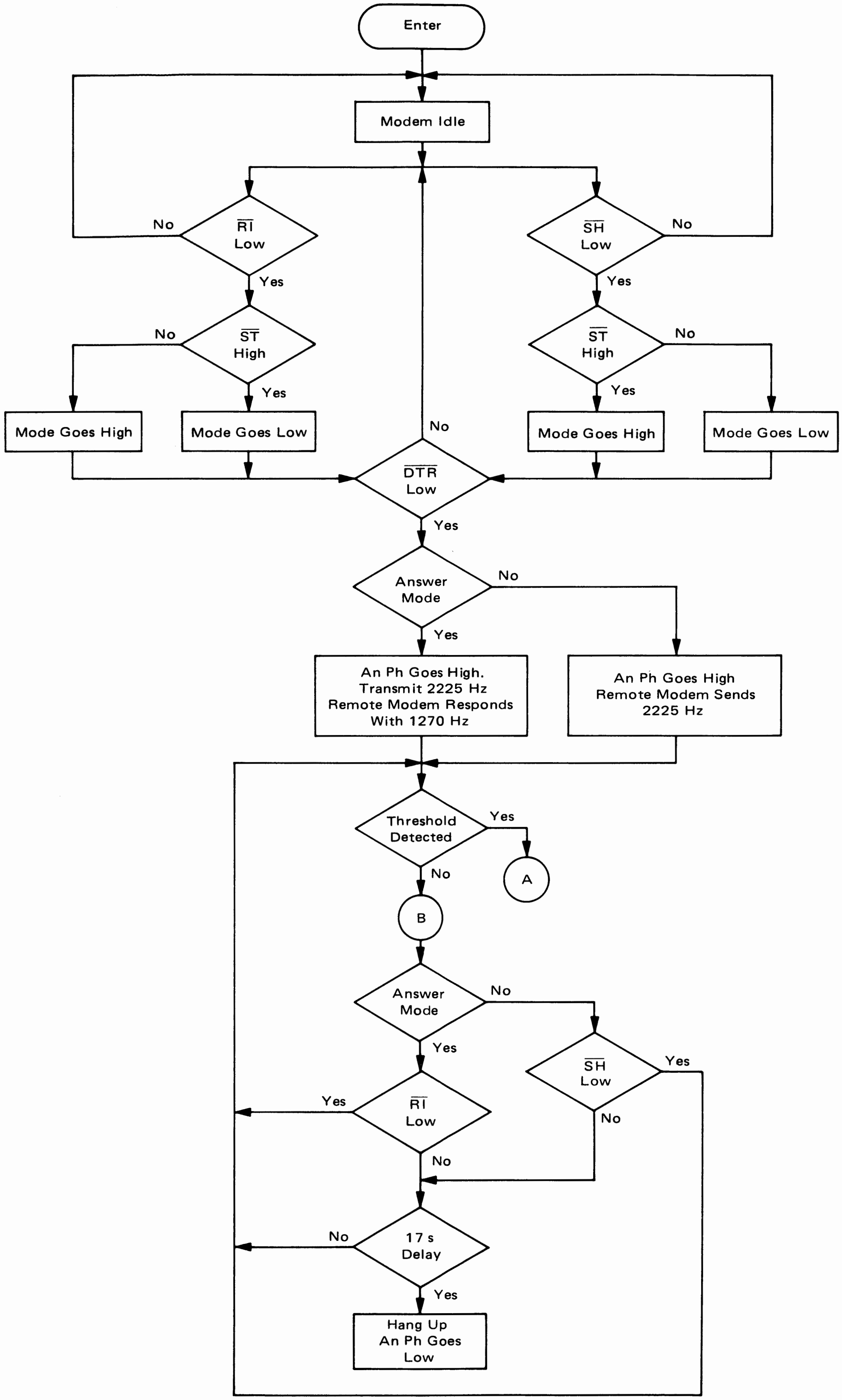


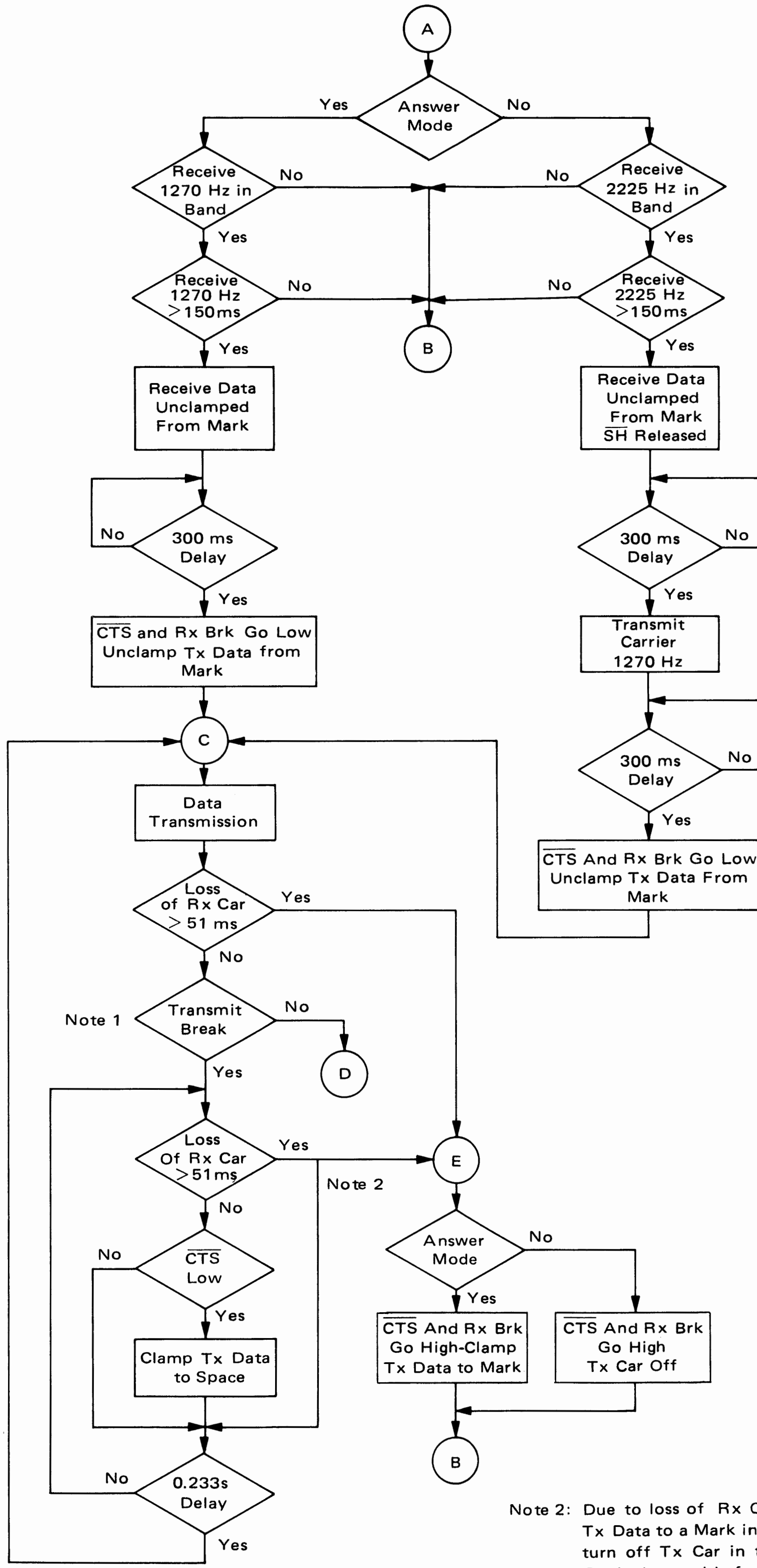
*Digital Representation

TABLE 2 – TRANSMIT BREAK AND DISCONNECT DELAYS

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

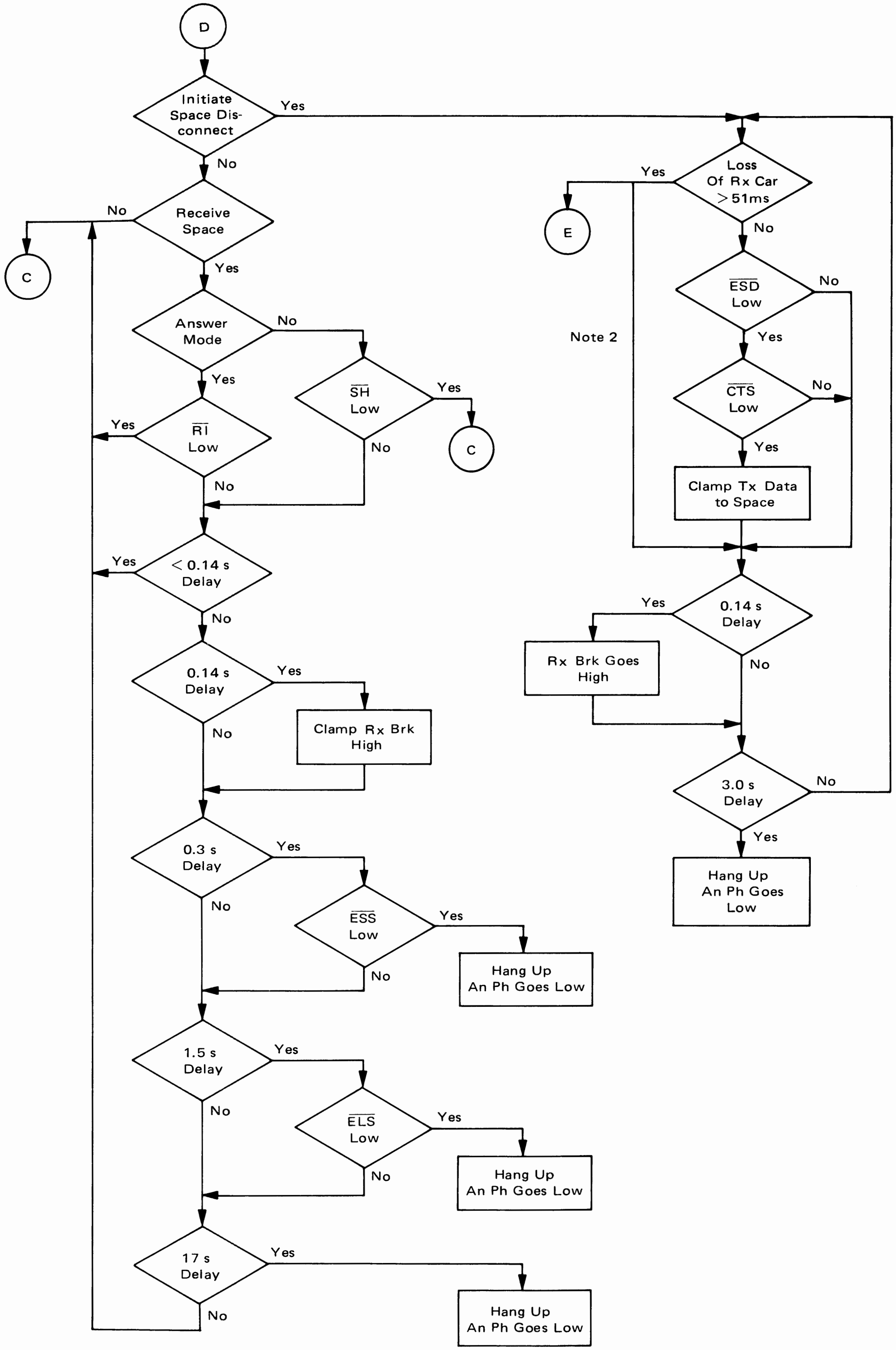
FIGURE 10 — FLOW DIAGRAM





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.

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


D
Initiate Space Dis-connect
Yes
No
Receive Space
No
C
Yes
Answer Mode
No
Yes
SH Low
Yes
C
No
RI Low
Yes
No
< 0.14 s Delay
Yes
No
0.14 s Delay
Yes
Clamp Rx Brk High
No
0.3 s Delay
Yes
ESS Low
Yes
Hang Up An Ph Goes Low
No
No
1.5 s Delay
Yes
ELS Low
Yes
Hang Up An Ph Goes Low
No
No
17 s Delay
Yes
Hang Up An Ph Goes Low
No
Loss Of Rx Car > 51ms
Yes
E
No
ESD Low
No
Yes
Note 2
CTS Low
No
Yes
Clamp Tx Data to Space
0.14 s Delay
Yes
Rx Brk Goes High
No
3.0 s Delay
No
Yes
Hang Up An Ph Goes Low