Single-Chip Modem Provides Low-Cost Data Communication

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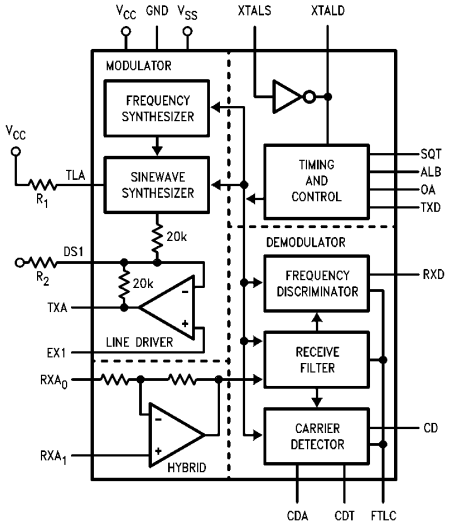
A simple modem provides an inexpensive way to link your IBM PC or compatible computer with a remote system. The modem, which transmits data asynchronously at 300 baud, is easy to build and features both autodial and autoanswer.

Using a simple design, you can build an inexpensive modem for your IBM PC or compatible computer. Based on a single chip that transforms digital computer data into analog frequencies, the modem lets you transmit data asynchronously via telephone lines at 300 baud. The circuit also uses a DTMF (dual-tone multiple-frequency) tone-dialer chip, a DAA (data-access arrangement) telephone-line interface, and a UART that handles autoanswer and autodial functions. Configured to operate in your PC's I/O address space, this modem circuit uses an equality detector and a 3-to-8-line decoder to decode address lines, I/O strobes, and DMA strobes.

The modem design is based on the MM74HC942 modem chip *Figure 1* illustrates the chip's architecture. By eliminating two external op amps, an on-chip line driver and a 2-to-4-wire hybrid simplify the task of interfacing to the telephone line. The line driver drives a 600Ω line through an external 600Ω terminating resistor, thus providing a nominal impedance match between the modem and the phone line. When the programmable level-adjust resistor R_1 is connected between the TLA pin and V_{CC}, the line driver transmits at levels approaching 0 dBm.

You can access the driver externally through the DSI and EXI pins (pins 1 and 18). The EXI input provides a set gain of about 2. The DSI input allows you to achieve an adjustable gain reaching 0 dBm via series resistor R_2. The gain is approximately $20k \div R_2$.



TL/F/8691–1

FIGURE 1. The MM74HC942's 2-to-4-wire hybrid and line driver let you use simple circuitry to interface your modem to the telephone line

Because the circuit communicates via 2-wire telephone lines, both incoming and outgoing signals enter the HC942. The on-chip line hybrid rejects the outgoing signal while passing the incoming signal to the demodulator. Under most phone-line conditions, the hybrid provides 10- to 20-dB transmit-carrier rejection. The receive filter of the demodulator section reduces the outgoing signal to negligible levels.

A LOOK AT THE MM74HC942 MODEM CHIP

The MM74HC942 modem IC lets you use simple support circuitry, requires relatively little circuit-board area, and consumes little power. Although the chip is functionally similar to others on the market, it includes an adjustable line driver and programmable carrier-detection circuitry, and it operates from ±5V supplies.

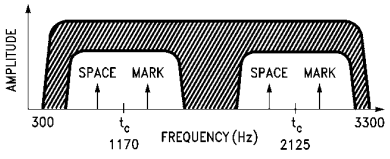
The chip's analog loopback (ALB) function and power-down mode provide self-testing and power conservation. You set the ALB function by holding the ALB input high, which causes the modulator to shunt its output to the input of the demodulator, providing a simple diagnostic self-test.

The power-conservation feature makes the HC942 power down when both the ALB and SQT inputs are high. The chip typically draws less than 50 μA in the power-down mode, so, for certain applications, you might have to add a battery for backup power.

Either the ALB or the SQT input can bring the chip out of its power-down mode, so you can use the HC942 in a bus-like configuration. Because the chip's inputs and outputs offer 3-state levels, either the ALB or SQT input can serve as a chip select when one of them is low.

MODULATOR CONVERTS DATA

In the modulator section of the modem IC, the frequency synthesizer generates clock frequencies for the sine-wave synthesizer. During transmission, digital data from the CPU or UART enters the TXD input on the HC942, which converts incoming ones and zeros to mark and space frequencies, respectively. The Originate/Answer ($O/\overline{A}$) input sets these frequencies into the upper or lower transmit bands *(Figure 2)*.



TL/F/8691–2

FIGURE 2. The HC942 modem chip converts incoming ones and zeros to mark and space frequencies when digital data enters the chip's TXD input

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A high signal on the O/$\overline{A}$ pin lets you originate a call. In the originate mode, the HC942 transmits in the lower band and receives in the upper band. In the answer mode, the chip transmits in the upper band and receives in the lower band. The chip's sine-wave synthesizer, which is essentially a D/A converter, decodes the output of the frequency synthesizer, producing an FSK output that's compatible with the Bell 103 standard. Table I shows the frequency assignments for both modes of operation.

Using a 9-pole switched capacitor, the demodulator passes incoming tones at the same time that it virtually eliminates locally transmitted signals. The demodulator's receive filter then transmits its output to a frequency discriminator, in which two detectors sense the mark and space frequencies, converting each frequency to a logical one or zero.

The receive filter also passes output to the carrier detector, which then compares the output of the filter with an externally adjustable voltage at the CDA pin. If you leave this pin floating or connect it to ac ground, the voltage at CDA is 1.2V. The threshold is nominally set on at −42 dBm and off at −45 dBm. When a carrier exceeds the upper threshold, the carrier detector activates the demodulator after a preset timing delay, forcing the $\overline{CD}$ output low. Timing capacitor C_6 at the CDT pin sets the carrier-detect delay. When the carrier level drops below the lower threshold point, the demodulator returns to a disabled state.

TABLE I. Bell 103 Tone Allocation

Data	Originate Mode		Answer Mode	
	Transmit	Receive	Transmit	Receive
Space	1070 Hz	2025 Hz	2025 Hz	1070 Hz
Mark	1270 Hz	2225 Hz	2225 Hz	1270 Hz

The interface hardware betweeen the HC942 and an IBM PC or compatible computer has four major parts: the decoding logic, the communication link, the tone dialer, and the DAA (*Figure 3*). The decoding logic addresses the two I/O address locations on the PC that are reserved for asynchronous communications. The primary location is $3F8_{HEX}$–$3FF_{HEX}$; the secondary location is $2F8_{HEX}$–$2FF_{HEX}$. When the decoding logic uses these two locations, this interface design is compatible with IBM PC software. (For other address locations, consult the documentation for your computer and for any other add-in cards your computer is using.)

The interface circuit employs an HCT688 equality detector and an HCT138 3-to-8-line decoder. When you connect the IOR and IOW strobes in a NAND configuration, the circuit generates the I/O strobe while the direct-memory-access (DMA) strobe acts as the AEN output from the IBM bus. The equality detector compares its corresponding P and Q inputs and checks to see whether P equals Q. When P and Q are equal, the P=Q output selects the HCT138 decoder and the HCT245 bidirectional bus driver.

The HCT138 further decodes the address lines, selecting as many as eight devices, although it enables only two: the TP5088 tone dialer and the 8250 UART. Output Y_7 directly enables the 8250. The Y_5 output, however, indirectly enables the TP5088 via an HC123 dual one-shot. This output triggers the one-shot, which activates the TP5088 for a predetermined time. The lower three address lines (A_2 through A_0) access the 8250's internal registers by addressing the UART directly.

The 8250 and the HC942 provide the serial communications link between the host and remote computers. During transmission, the UART converts parallel data from the μP to serial data for the HC942. The HC942 receives this data at its TXD input and transmits an FSK output at the TXA output. During data reception, the HC942 receives incoming tones at the RXA_1 input, demodulates the tones, and sends serial data through the RXD output to the 8250.

Because the HC942 doesn't require an external line driver or a hybrid, the modem circuit requires only a few passive components. Resistor R_{12} sets the line driver's transmit level (Table II) at the same time that C_6 adjusts the carrier-detect timing circuit. This circuit waits a predetermined time (the time period is a function of the RC time constant) before responding to a carrier and sending the $\overline{CD}$ (Carrier Detected) output high. In addition, the circuit delays for a short time before dropping the $\overline{CD}$ output low again. Use the following equations to find the appropriate delay times:

$$T_{OFF\text{-}TO\text{-}ON} = 6.4 \times C$$

and

$$T_{ON\text{-}TO\text{-}OFF} = 0.54 \times C$$

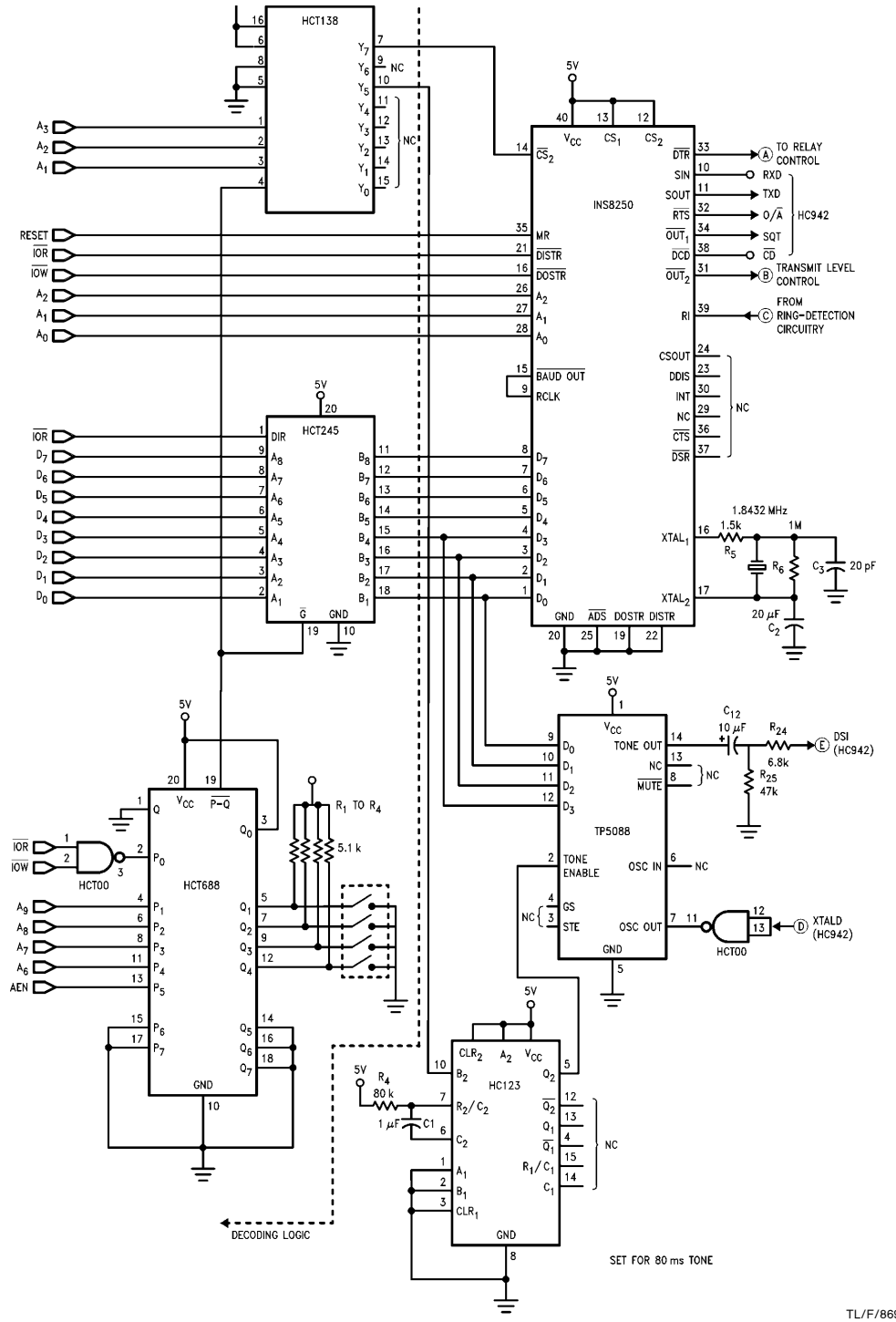
where C is in μF and T is in seconds. The first equation gives the delay before transmission begins; the second gives the delay before transmission ends. Note that these times differ considerably. When the modem is preparing to transmit, it must delay long enough to ensure that the carrier is stable; carrier stability is not as critical when the modem is preparing to stop transmitting.

The HC942 uses a common 3.579-MHz crystal (without loading capacitors) to generate all the internal timing and modulated sine waves. The crystal also drives the TP5088's oscillator. It doesn't, however, drive the 8250's oscillator, because IBM PC software requires the 8250 to use a 1.8432-MHz crystal. You can adjust the carrier-detection trip points by applying an external voltage at the CDA (Carrier-Detect Adjust) pin. When you double the nominal voltage (1.2V), the trip points increase by 6 dB. Similarly, when you cut the voltage in half, the trip points decrease by 6 dB.

TABLE II. Standard Resistor Values*

Transmit Level (dBm)	Transmit Level Adjust Resistor $R_{12}(\Omega)$
−12	OPEN
−11	19.8k
−10	9.2k
−9	5.49k
−8	3.61k
−7	2.52k
−6	1.78k
−5	1.24k
−4	866
−3	562
−2	336
−1	150
0	0

*UNIVERSAL SERVICE ORDER CODE



TL/F/8691–3

FIGURE 3a. The interface hardware between the HC942 and the computer (an IBM PC or compatible) comprises four major parts: the decoding logic, the communication link, the tone dialer, and the data-access arrangement (DAA).

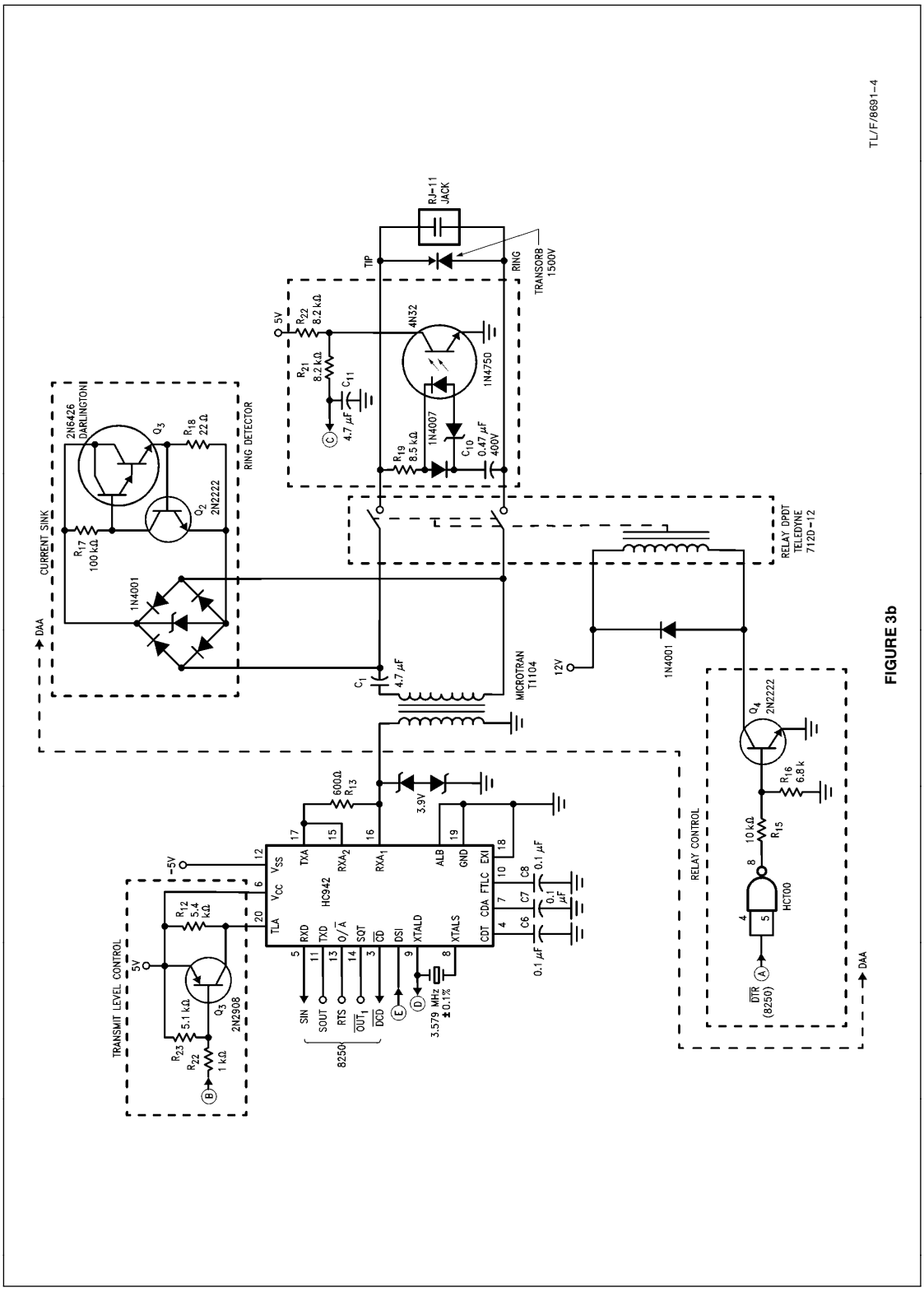

TL/F/8691–4
RJ-11 JACK
TIP
RING
TRANSORB 1500V
5V
R_{22} 8.2 kΩ
R_{21} 8.2 kΩ
C_{11} 4.7 µF
4N32
1N4750
1N4007
C_{10} 0.47 µF 400V
R_{19} 8.5 kΩ
RELAY DPDT TELEDYNE 712D-12
DAA
CURRENT SINK
2N6426 DARLINGTON
Q_3
R_{18} 22 Ω
Q_2 2N2222
R_{17} 100 kΩ
1N4001
RING DETECTOR
C_1 4.7 µF
MICROTRAN T1104
12V
1N4001
Q_4 2N2222
R_{16} 6.8 k
R_{15} 10 kΩ
HCT00
RELAY CONTROL
$\overline{DTR}$ (8250)
DAA
600Ω R_{13}
3.9V
-5V
HC942
TLA
V_{CC}
V_{SS}
TXA
RXA_2
RXA_1
ALB
GND
EXI
FTLC
CDA
CDT
RXD
TXD
O/$\overline{A}$
SQT
$\overline{CD}$
DSI
XTALD
XTALS
0.1 µF
C_8
C_7
C_6
SIN
SOUT
RTS
$\overline{OUT_1}$
$\overline{DCD}$
8250
3.579 MHz ±0.1%
TRANSMIT LEVEL CONTROL
R_{12} 5.4 kΩ
R_{23} 5.1 kΩ
R_{22} 1 kΩ
Q_3 2N2908

FIGURE 3b

Because the modem operates in full-duplex mode, most of the handshake signals—Data Terminal Ready (DTR), Clear To Send (CTS), etc—operate as general-purpose control signals. You need to use only the DCD (Data Carrier Detect) and RI (Ring Indication) signals. To control the modem, the UART switches the HC942 into the originate/answer mode and the squelch mode (modulator disabled) through outputs $\overline{RTS}$ and $\overline{OUT1}$. The 8250 also closes the on/off-hook-switch relay through output $\overline{DTR}$.

The 8250 receives status information from the carrier-detection and ring-detection circuits. When a carrier is present, the internal carrier detector of the HC942 sends a Carrier Detected signal to the $\overline{DCD}$ input port of the 8250. This signal gives the cue to begin data communication. Similarly, the ring detector in the DAA sends a signal to the $\overline{RI}$ input port during a ring signal.

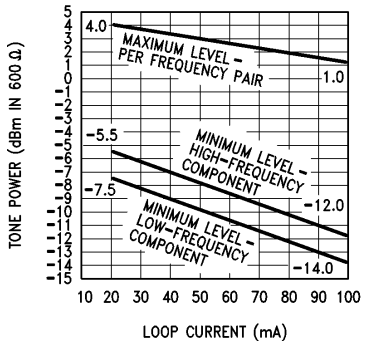
The DTMF tone dialer operates by summing two tones, one from a low group and one from a high group (Table III). The tone dialer then sends the composite tone to the telephone company's central office. The TP5088, which can directly decode a 4-bit binary code, becomes active when the Tone Enable receives a low-to-high transition, and it remains active as long as the input stays high. This input is connected to the HC123 one-shot, which sets the duration of the DTMF tone. The FCC requires that tone duration have a minimum cycle time of 100 ms, a pulse duration of 50 ms, a minimum interdigit interval of 45 ms, and a maximum interdigit interval of 3 sec.

TABLE III. Functional Truth Table

Keyboard Equivalent	Data Inputs				Tone Enable	Tones Out		Mute
	D_3	D_2	D_1	D_0		f_L(Hz)	f_H(Hz)	
X	X	X	X	X	0	0V	0V	0V
1	0	0	0	1	⌒	697	1209	O/C
2	0	0	1	0	⌒	697	1336	O/C
3	0	0	1	1	⌒	697	1477	O/C
4	0	1	0	0	⌒	770	1209	O/C
5	0	1	0	1	⌒	770	1336	O/C
6	0	1	1	0	⌒	770	1477	O/C
7	0	1	1	1	⌒	852	1209	O/C
8	1	0	0	0	⌒	852	1336	O/C
9	1	0	0	1	⌒	852	1477	O/C
0	1	0	1	0	⌒	941	1336	O/C
*	1	0	1	1	⌒	941	1209	O/C
#	1	1	0	0	⌒	941	1477	O/C
A	1	1	0	1	⌒	697	1633	O/C
B	1	1	1	0	⌒	770	1633	O/C
C	1	1	1	1	⌒	852	1633	O/C
D	0	0	0	0	⌒	941	1633	O/C

Before coupling a tone dialer to the phone lines, you must make sure the dialer meets certain FCC guidelines. For instance, you must maintain specified dc voltages and loop currents for all loop lengths, match the impedance to the phone line, and provide tones within specified amplitude and distortion limits.

By designing the DAA correctly, you can make your tone dialer meet the first two of these guidelines. Because the 5088 generates low tone distortion, you can ignore the distortion limit. However, you must boost the 5088's output levels to the output levels shown in *Figure 4*. Using the internal line driver of the HC942, you can raise the 5088's minimum output level to 0 dBm. Transistor Q_4 raises the output level of the line driver to its maximum by shorting the transmit-level adjustment resistor R_{12}.



TL/F/8691–5

FIGURE 4. Although the TP5088 tone dialer allows you to ignore distortion limits, you must boost its output levels to conform with the FCC limits shown here.

DAA PERFORMS DUAL FUNCTIONS

The DAA is both a protective device and a functional modem interface. Although the DAA is simple, you should submit your final design to qualified testers to ensure that your circuit conforms to FCC rules (part 68 and part 15).

In its protective capacity, the DAA provides surge protection from natural hazards (like lightning) and from induced voltages generated by relay coils. The DAA also provides dc isolation between the phone line and the modem. Its modem-interface functions include ring detection and on- and off-hook control. The DAA's ring-detection circuit sends a signal to the CPU via the 8250 (shown in *Figure 3a*) when an incoming ring occurs. On- and off-hook control takes place via a relay that the 8250 controls with its $\overline{DTR}$ signal.

The DAA has three sections: the transformer, the relay, and the ring detector. The circuit's 600Ω 1:1 transformer isolates the modem from the phone lines, preventing line interference. For voice and data communication, the transformer must have a flat frequency response from 300 to 3300 Hz with little harmonic distortion. As you can see from *Figure 3b*, a current sink (Q_2 and Q_3) is connected in parallel with the transformer. The diode drop across R_{18} shunts excess current.

The current flowing through telephone lines varies from 20 to 120 mA. If your design requires a transformer that can't handle at least 30 mA, you'll need to add the current sink to shunt the excess current from the phone line, preventing transformer saturation. Of course, if you were to use a transformer that could handle more than 30 mA, you wouldn't need a current sink, but the transformer would be both heavy and expensive.

A relay in the DAA provides on- and off-hook control. By closing, the relay switches the modem off-hook and connects the DAA to the telephone line. The $\overline{DTR}$ signal from the 8250 controls this relay by switching Q_4 on. This transistor allows current to flow through the relay and close its contacts. A dpdt relay completely isolates the relay-control circuit when the modem is on-hook.

The ring-detector circuit in *Figure 3b* sends a signal to the CPU via the 8250 when an incoming ring occurs. Because the incoming ring signal is nominally 90V rms, you can't couple it directly to the DAA. The ring detector includes a 27V zener diode, a capacitor (C_{10}), and an optocoupler. The zener diode prevents noise from tripping the ring detector. C_{10} creates a high dc impedence so that the ring detector won't affect other circuits in the DAA. Note that C_{10} must be able to accommodate high voltages, such as the high amplitude of the ring signals. The optocoupler provides isolation and translates the high-voltage ring signals into digital levels.

The optocoupler toggles on and off during a ring, producing a series of low-going pulses. An RC network (R_{21} and C_{11}) smoothes these pulses to a single low pulse. The 8250 receives this pulse at its $\overline{RI}$ (ring indication) input port. The μP detects the ring by polling this port or by servicing the generated interrupt.

PC EMULATES A DUMB TERMINAL

The communication program for the modem (the listing begins next page) consists of three routines (for autodial, autoanswer, and terminal emulation). The first two routines establish a connection by either dialing a number or answering a call. The main terminal routine then configures the IBM to act as a dumb terminal that transmits to the phone line all characters you enter from the keyboard and displays all incoming characters on the CRT. The program is menu driven; you select either the autodial or the autoanswer routine. At the end of these routines, control jumps either to the terminal program or to the main menu. You use the ''table of equates'' at the beginning of the program to set up the initialization parameters.

The communication program frequently accesses the modem registers to control outputs $\overline{DTR}$, $\overline{RTS}$, and $\overline{OUT1}$. It also polls the line status register to read status-input ports $\overline{RI}$ and $\overline{DCD}$.

When you select the autoanswer option from the menu, the routine begins by polling bit 6 of the modem's status register to detect incoming calls. When a ring occurs, this bit goes high. The modem does not immediately go off-hook, however, because the ring signal's high voltage causes arcing between the relay contacts. Instead, the program delays answering for 2.5s, lifting the modem off-hook between rings. The modem goes off-hook by setting bits 0 and 1 of the modem's control register low. The $\overline{RTS}$ and $\overline{DTR}$ outputs, in turn, go low. These outputs then switch the HC942 into the answer mode by closing the relay to establish a connection.

After the modem answers the telephone, a 2s billing delay must occur (according to FCC regulations) before transmission can begin. During this period, the telephone company's central offices exchange the callers' billing information. A software delay keeps bit 2 of the modem's control register low, ensuring that the HC942 engages the squelch function during this period. After the billing delay, the HC942 disengages the squelch function, and the μP polls bit 7 of the modem's status register. If bit 7 is high, a carrier is present, and data communication can begin. The autoanswer routine then jumps to the main program to transmit and receive data. If the other computer fails to respond with a carrier, the autoanswer routine times out, and control returns to the main menu.

The autodial routine first asks you whether you want to make a long-distance or a local call and then enters the phone number into buffer BUFF1. Next, the modem dials the phone number by fetching a digit from the buffer and sending it to the TP5088. The μP then waits 200 ms. During this period, the HC123 one-shot enables the TP5088 for 80 ms and then disables it for the remaining 120 ms. Therefore, each digit comprises an 80 ms DTMF tone followed by 120 ms of silence. After the modem dials the phone number, the μP polls bit 7 in the status register to see if a carrier is present. Modem operation then takes place as in the autoanswer mode.

The main program enters either from the autodial or the autoanswer routine. It polls the line status register (LSR) and the modem's control register (MCR) to determine whether characters from the keyboard or the telephone line are present and to detect transmission errors or carrier loss.

When keyboard characters are present, bit 5 of the LSR goes high; when line characters are present, bit 0 goes high. The μP then reads the characters from the UART. Bits 1, 2, and 3 of the LSR indicate transmission errors; when such errors occur, the CRT displays a question mark. Bit 7 of the MCR indicates carrier loss. If the main program detects carrier loss during transmission, it disconnects the modem and returns to the main menu.

```
COMMUNICATIONS PROGRAM for the HC942.
;
;  Table of Equates
;
TP5088  EQU       2E8H              ;ADDR. OF TP5088
RBR     EQU       2F8H              ;RECEIVER BUFFER REG.
THR     EQU       RBR               ;TRANSMITTER HOLDING REG.
LDL     EQU       RBR               ;LOWER DIVISOR LATCH
IER     EQU       RBR+1             ;INTR. ENABLE REG.
UDL     EQU       RBR+1             ;UPPER DIVISION LATCH
IIR     EQU       RBR+2             ;INTR. ID. REG.
LCR     EQU       RBR+3             ;LINE CONTROL REG.
MCR     EQU       RBR+4             ;MODEM CONTROL REG.
LSR     EQU       RBR+5             ;LINE STATUS REG.
MSR     EQU       RBR+6             ;MODEM STATUS REG.
SCR     EQU       RBR+7             ;SCRATCH REG.
BAUD1   EQU       0F4H              ;LOWER BAUD RATE DIVISOR
BAUD2   EQU       1                 ;UPPER BAUD RATE DIVISOR
LCNTL   EQU       07H               ;DATA CONTROL - 8 DATA BITS, 2 STOP
                                    ;               BITS, NO PARITY
LOCPH   EQU       90                ;DIGIT COUNTER FOR LOCAL PHONE NO.
LDPH    EQU       120               ;DIGIT COUNTER FOR LONG DIS. PH NO.
;
STACK SEGMENT PARA STACK 'STACK'
        DB        256   DUP(0)
STACK ENDS
;
DATA SEGMENT PARA PUBLIC 'DATA'
        BUFF      DB    256 DUP(0)      ;BUFFER FOR PHONE NUMBER
        MSG1      DB    '*** IN DIALING MODE ***                  '
        MSG2      DB    'Is call long distance? (Y/N)             '
        MSG3      DB    'Enter long dis. ph.no. (1-AAA-PPP-SSSS) '
        MSG4      DB    'Enter local ph. no.    (9-PPP-SSSS)     '
        MSG5      DB    'No answer, call again? (Y/N)             '
        MSG6      DB    'Dialing and waiting for a response....  '
        MSG7      DB    '*** MODEM COMMUNICATIONS PROGRAM ***     '
                  DB    '   1 ..... Dial a number                '
                  DB    '   2 ..... Auto-answer routine          '
                  DB    '   3 ..... Exit and return to DOS       '
        MSG8      DB    ' *** Phone line has been disconnected.  '
        MSG9      DB    'Carrier Detected. Phone is connected    '
        MSG10     DB    '**** AUTO-ANSWER MODE ****               '
                  DB    'Strike any key to exit mode              '
        MSG11     DB    'Ring detected, waiting for carrier...   '
        MSG12     DB    'No carrier detected, phone disconnected.'
        ERR       DB    '...Invalid entry, re-enter phone no.    '
DATA ENDS
```

COMMUNICATIONS PROGRAM for the HC942 (Continued)

```
;
CODE SEGMENT PARA PUBLIC 'CODE'
        PUBLIC    START1
START1 PROC FAR
;
;  Program Prolog
;
        ASSUME    CS:CODE
        PUSH      DS
        MOV       AX,0
        PUSH      AX
        MOV       AX,DATA
        MOV       DS,AX
        ASSUME    DS:DATA
;
;  Initialize the Line Control Register of UART
;      - No. of data and stop bits, baud rate, and parity of
        or no parity
        MOV       DX,LCR            ;LINE CONTROL REG
        MOV       AL,80H            ;PREPARE FOR BAUD RATE DIV.
        OUT       DX,AL
        MOV       DX,LDL            ;LOWER DIVISOR LATCH
        MOV       AL,BAUD1          ;  LOWER DIVISOR
        OUT       DX,AL
        MOV       DX,UDL            ;UPPER DIVISOR LATCH
        MOV       AL,BAUD2          ;  UPPER DIVISOR
        OUT       DX,AL
        MOV       DX,LCR            ;LINE CONTROL REG.
        MOV       AL,LCNTL          ; UART DATA CONTROL
                                    ;  See EQU for data control
        OUT       DX,AL
;
;  Disable interrupts of 8250 UART
;
        MOV       DX,IER            ;INTR. ENABLE REG.
        MOV       AL,0              ;DISABLE ALL INTR. OF 8250
        OUT       DX,AL
;
;  Select Auto-dial or Auto-answer routine
;
MENU:   MOV       BX,OFFSET MSG7            ;SHOW OPENING MESSAGE
        CALL      DISPLAY
        CALL      CR--LF                    ;<CR> AND <LF>
        CALL      DISPLAY
        CALL      DISPLAY
        CALL      DISPLAY
        CALL      CR--LF
        CALL      INPCHAR
        CALL      DISPCHAR
        CALL      CR--LF                    ;<CR> AND <LF>
```

COMMUNICATIONS PROGRAM for the HC942 (Continued)

```
        CMP       AL,'1'                    ;GOTO AUTO-DIAL ROUTINE IF "1"
        JE        DIAL
        CMP       AL,'2'                    'GOTO AUTO-ANS IF "2"
        JE        ANSW
        RET                                 ;RETURN TO DOS
;
;  **** AUTO-ANSWER MODE ****
;
; This routine answers the phone 2.5 seconds after ring is detected.
; If after 10 seconds no carrier is detected, program returns to the menu.
;
ANSW:   MOV       BX,OFFSET MSG10 ;DISPLAY AUTO-ANS MESSAGE
        CALL      DISPLAY
        CALL      DISPLAY
AANS:   MOV       AH,1
        INT       16H
        JNZ       MENU1             ;EXIT IF ANY KEY IS STRUCK
        MOV       DX,MCR            ;MODEM CONTROL REG.
        IN        AL,DX
        TEST      AL,40H            ;TEST RING INDICATOR -- RI=1
        JZ        AANS
        JMP       RING
MENU1:  CALL      INPCHAR           ;CLEAR CHAR. IN KEYBOARD
        JMP       MENU
;
;  Wait for 2.5 seconds after ring is detected
;
RING:   MOV       CI,12             ;LOAD DELAY COUNTER
WAIT1:  NOP
        CALL      DELAY             ;DELAY FOR 0.2 SEC
        LOOP      WAIT1
        MOV       BX,OFFSET MSG11   ;RING HAS BEEN DETECTED
        CALL      DISPLAY
;
;  Switch MODEN into answer mode -- 0/Ā=0
;
        MOV       DX,MCR            ;MODEM CONTROL REG.
        MOV       AL,3              ;DTR=0, RTS=0, OUT1=1 IN ANS. MODE AND
;                                    MODEM SQUELCHED
        OUT       DX,AL
;
; Wait for 2 second billing delay
;
        MOV       CX,12D            ;LOAD DELAY COUNTER
WAIT2:  NOP
        CALL      DELAY
        LOOP      WAIT2
        MOV       DX,MCR            ;MODEM CONTROL REG.
        MOV       AL,7              ;DTR=0, RTS=0, OUT1=0 MODEM UNSQCH
        OUT       DX,AL
```

COMMUNICATIONS PROGRAM for the HC942 (Continued)

```
;
;  Poll for carrier. Timeout after 10 seconds
;
        MOV       CX,500            ;LOAD TIMEOUT COUNTER
CARR:   MOV       DX,MSR
        IN        AL,DX
        TEST      AL,80H            ;TEST FOR CARRIER -- DCD=1
        JMZ       COMM1
        CALL      DELAY             ;WAIT 0.2 SEC THEN POLL AGAIN
        LOOP      CARR
        JMP       NC
COMM1:  JMP       COMM              ;GO TO MAIN PROGRAM

;
;  No carrier detected after answering phone, hang up and go back
;  to auto-answer routine
;
NC:     MOV       BX,OFFSET MSG12
        CALL      DISPLAY
        MOV       DX,MCR            ;MODEM CONTROL REG.
        MOV       AL,00             ;CODE TO HANG UP PHONE
        OUT       DX,AL
        JMP       ANSW
;
;  **** DIALING ROUTINE ****
;
;  Determine long distance or local call
;
DIAL;   MOV       BX,OFFSET MSG1    ;DISPLAY OPENING MESS.
        CALL      DISPLAY
IMP:    MOV       BX,OFFSET MSG2    ;" LONG DISTANCE? "
        CALL      DISPLAY
        CALL      INPCHAR           ;INPUT CHAR.
        CALL      DISPCHAR          ;DISPLAY CHAR.
        CALL      CR--LF            ;<CR> AND <LF>
        CMP       AL,'N'            ;IS CHAR. A "n" OR A "N"
        JE        SHT
        CMP       AL,'n'
        JE        SHT
;
;  Enter long distance phone number into buffer
;
        MOV       BX,OFFSET MSG3    ;PROMPT FOR LONG DIS. CALL
        CALL      DISPLAY
        MOV       BX,OFFSET BUFF    ;STARTING OFFSET OF BUFFER
        MOV       CL,LDPH           ;COUNTER LONG DIS. PH. NUMBER AND <CR>
        CALL      BUFFER            ;ENTER PH. NO. INTO BUFFER
        CALL      CR--LF            ;<CR> AND <LF>
        JMP       OFFHK
```

COMMUNICATIONS PROGRAM for the HC942 (Continued)

```
;
;  Enter local phone number into buffer
;
SHT:    MOV       BX,OFFSET MSG4     ;PROMPT FOR LOCAL CALL
        CALL      DISPLAY
        MOV       BX,OFFSET BUFF     ;STARTING OFFSET OF BUFFER
        MOV       CL,LOCPH           ;COUNTER FOR LOCAL PH. NUMBER AND <CR>
        CALL      BUFFER
        CALL      CR--LF             ;<CR> AND <LF>
;
;  Take phone off-hook -- DTR=0. OUT1=1, OUT2=0
;
OFFHK:  MOV       DX,MCR             ;MODEM CONTROL REG.
        MOV       AL,05H             ;DTR=0, OUT1=1,
        OUT       DX,AL              ;  OUT2=0 MODEM IS POWERED DOWN
;
;  Wait for 2 sec. to get a dial tone
;
        MOV       CX,100
LOOP2:  NOP
        CALL      DELAY              ;WAIT FOR 200 ms
        LOOP      LOOP2              ;LOOP BACK 10 TIMES FOR A TOTAL OF 2000 ms
;
;  Dial phone number: Get number from buffer, send data to TP5088 for
;                     80 ms and off 120 ms. This is continued until a
;                     <CR> is encountered.
;
        CLI                          ;DISABLE INTR. OF 8088
        MOV       BX,OFFSET MSG6     ;DISPLAY MESSAGE6
        CALL      DISPLAY
        CALL      CR--LF             ;<CR> AND <LF>
        MOV       BX,OFFSET BUFF     ;MOVE TO STARTING ADDR. OF BUFFER
LOOP3:  MOV       DX,TP5088          ;ADDR. TP5088
        MOV       AL,[BX]            ;INPUT CHAR. FROM BUFFER
        CMP       AL,0DDH            ;IS CHAR. A DD HEX
        JE        CD                 ;YES, END DIALING
        OUT       DX,AL
        CALL      DELAY              ;WAIT 200 ms
        INC       BX
        JMP       LOOP3
;
;  Wait for carrier detection or timeout
;
CD:     STI                          ;ENABLE INTR. OF 8088
        MOV       DX,MCR             ;MODEM CONTROL REG.
        MOV       AL,1               ;TAKE MODEM OUT OF POWER DOWN MODE
        OUT       DX,AL
        CALL      DELAY              ;WAIT FOR 0.4 SEC
        CALL      DELAY
        MOV       CX,1000
```

COMMUNICATIONS PROGRAM for the HC942 (Continued)

```
LOOP4   MOV     DX,MSR          ;MODEM STATUS REG.
        IN      AL,DX
        TEST    AL,80H          ;TEST FOR DCD=0
        JNZ     COMM
        CALL    DELAY           ;WAIT 200 ms, THEN CK, DCD AGAIN
        LOOP    LOOP4
;
  No answer after 20 sec., hang up, then call again or return to DOS?
;
        MOV     DX,MCR          ;MODEM CONTROL REG.
        MOV     AL,00           ;CODE TO UART TO HANG UP PHONE
        OUT     DX,AL
        MOV     BX,OFFSET MSG5  ;" NO ANS., CALL AGAIN? "
        CALL    DISPLAY
        CALL    INPCHAR         ;INPUT CHAR.
        CALL    DISPCHAR        ;ECHO CHAR.
        CALL    CR--LF          ;<CR> AND <LF>
        CMP     AL,'Y'          ;IS CHAR. A "Y" OR A "y"
        JE      BACK
        CMP     AL,'y'
        JE      BACK
        JMP     MENU            ;GO BACK TO MAIN MENU
BACK:   JMP     OFFHK
;  **** MAIN PROGRAM ****
;  This is the communication routine. The Line Status
;  Register is constantly polled for incoming and outgoing
;  characters.
;
COMM:   MOV     DX,MCR          ;MODEM CONTROL REGISTER
        MOV     AL,05H          ;DTR=0, OUT1=0 -- MODEM IS UNSQUELCHED
        OUT     DX,AL
        MOV     BX,OFFSET MSG9  ;INDICATE THAT CARRIER IS DETECTED
        CALL    DISPLAY
        CALL    CR--LF          ;<CR> AND <LF>
MAIN:   MOV     DX,LSR          ;LINE CONTROL REG.
        IN      AL,DX           ;INPUT LINE STATUS FROM UART
        TEST    AL,1EH          ;ERROR CONDITION?
        JNZ     ERROR
        TEST    AL,01H          ;DATA RECEIVED?
        JNZ     REC
        TEST    AL,20H          ;TRANSMISSION READY?
        JZ      MAIN
        MOV     DX,MSG          ;MODEM STATUS REG.
        IN      AL,DX
        TEST    AL,80H          ;DCD=1? OR DATA CARRIER LOST?
        JZ                      RTRN
;
;  Check keyboard for key strike
;
        MOV     AH,1
        INT     16H
        JZ      MAIN            ;POLL AGAIN IF NO KEY STRIKE
```

COMMUNICATIONS PROGRAM for the HC942 (Continued)

```
;
;  Input character from keyboard and send it to the UART
;
        MOV       AH,0
        INT       16H
        MOV       DX,THR            ;TRANSMISSION HOLDING REG.
        OUT       DX,AL             ;SEND CHAR. TO UART
        JMP       MAIN
;
;  **** Data received routine: read data from UART and display it
;
;  Read data from the UART
;
REC:    MOV       DX,RBR            ;REC. BUFFER REG.
        IN        AL,DX
        AND       AL,7FH            ;STRIP OFF MSB
        PUSH      AX                ;SAVE AX
;
;  Display character obtain from UART
;
        MOV       BX,0
        MOV       AH,14
        INT       10H               ;DISPLAY CHAR. ON CRT
        POP       AX                ;RESTORE AX
        CMP       AL,0DH            ;IS CHAR A <CR>?
        JE        CR
        CMP       AL,03H            ;IS CHAR. A ^C?
        JE        RTRN
        JMP       MAIN
;
;  If <CR> is hit, then add a <LF>
;
CR:     MOV       AL,0AH            ;<LF>
        MOV       BX,0
        MOV       AH,14
        INT       10H
        JMP       MAIN
;
;  If ^C is hit, then hang up and return to main menu
;
RTRN:   MOV       BX,OFFSET MSG8
        CALL      DISPLAY
        MOV       DX,MCR            ;MODEM CONTROL REG.
        MOV       AL,00             ;SEND CODE TO UART HANG UP PH. LINE
        OUT       BX,AL
        JMP       MENU              ;RETURN TO MAIN MENU
;
;  **** Error routine: display a "?" if there is a transmission error
;
ERROR:  MOV       DX,RBR            ;RECEIVER BUFFER REG.
        IN        AL,BX             ;CLEAR REC. BUFFER OF ERRONEOUS DATA
        MOV       AL,'?'
        MOV       BX,0
```

COMMUNICATIONS PROGRAM for the HC942 (Continued)

```
        MOV     AH,14
        INT     10H             ;DISPLAY A "?' ON CRT
        JMP     MAIN
;*****************************************************************************
;
;
;  "BUFFER" subroutine - places phone number in buffer (BUFF)
;               Entry:   BX=offset of buffer
;                        CL=counter of phone number digits
;               Output:  BX,CL altered
;
;*****************************************************************************
        PUBLIC BUFFER
BUFFER PROC NEAR
        MOV     CH,CL           ;SAVE DIGIT COUNTER
INPT:   CALL    INPCHAR         ;INPUT CHAR.
        CALL    DISPCHAR        ;ECHO CHAR.
        CMP     AL,'-'          ; IS CHAR. A '-'
        JE      INPT
        CMP     AL,'0'          ;IS CHAR. A "0"
        JE      ZERO
        PUSH    AX              ;SAVE AX
        SUB     AL,30H          ;CONVERT ASCII TO BINARY
        MOV     [BX],AL         ;MOVE DIGIT INTO BUFFER
CONT:   INC     BX
        DEC     CL
        POP     AX
        CMP     AL,00H          ;IS CHAR. A <CR>?
        JE      CX
        JMP     INPT
CK:     CMP     CL,0            ;IS COUNTER=0
        JE      EXIT1
        MOV     BX,OFFSET ERR   ;DISPLAY ERROR MESSAGE IF BAD ENTRY
        CALL    DISPLAY
        MOV     BX,OFFSET BUFF  ;RE-ENTER STARTING OFFSET OF BUFFER
        MOV     CL,CH           ;RE-ENTER DIGIT COUNTER
        JMP     INPT
ZERO:   PUSH    AX              ;SAVE AL
        MOV     AL,0AH          ;CODE TO DIAL A ZERO
        MOV     [BX],AL         ;MOVE "ZERO" DIGIT INTO BUFFER
        JMP     CONT
EXIT1:  RET                     ;RETURN TO PHONE DIAL ROUTINE
BUFFER  ENDP
;*****************************************************************************
;
;  "DELAY" subroutine - waits for 200 ms
;               Entry:   none
;               Output:  all register preserved
;
;*****************************************************************************
        PUBLIC DELAY
```

COMMUNICATIONS PROGRAM for the HC942 (Continued)

```
DELAY PROC NEAR
        PUSH      CX
        MOV       CX,34000D          ;LOOP BACK 34,000 TIMES
LOOP5:  NOP
        ADD       AL,1
        SUB       AL,1
        LOOP      LOOP5
        POP       CX
        RET                          ;RETURN TO PHONE DIAL ROUTINE
DELAY   ENDP
;*******************************************************************************
;
;  "INPCHAR" subroutine - invokes BIOS routine to input char. from keybd.
;                 Entry:   none
;                 Output:  AL=character entered from keyboard
;*******************************************************************************
        PUBLIC INPCHAR
INPCHAR PROC NEAR
        MOV       AH,0
        INT       16H
        RET
INPCHAR ENDP
;*******************************************************************************
;
;  "DISPLAY" subroutine - display a character string stored in the data
;                         segment.
;                 Entry:   BX=offset of message string
;                 Output:  BX altered
;
;*******************************************************************************
        PUBLIC DISPLAY
DISPLAY PROC NEAR
        PUSH      CX
        PUSH      AX
        MOV       CX,40D             ;CHAR. STRING IS 40 CHAR. LONG
DISP1:  MOV       AL,[BX]            ;SET CHAR. FROM DATA SEG.
        CALL      DISPCHAR           ;DISPLAY CHAR.
        INC       BX
        LOOP      DISP1
        CALL      CR--LF
        POP       AX
        POP       CX
        RET                          ;RETURN TO PHONE DIAL ROUTINE
DISPLAY ENDP
;*******************************************************************************
;
;  "DISPCHAR" subroutine - invokes BIOS routine to display a character
                           in AL on the screen
;                 Entry:   AL=character to be displayed
;                 Output:  AX altered
;
;*******************************************************************************
        PUBLIC DISPCHAR
```

COMMUNICATIONS PROGRAM for the HC942 (Continued)

```
DISPCHAR PROC NEAR
        PUSH       BX
        MOV        BX,0
        MOV        AH,14
        INT        10H
        POP        BX
        RET                          ;RETURN TO PHONE DIALING ROUTINE
DISPCHAR ENDP
;*******************************************************************************
;
;  "CR--LF" subroutine - produces a carriage return and line feed
;                Entry:   none
;                Output:  all register preserved
;
;*******************************************************************************
        PUBLIC CR--LF
CR--LF PROC NEAR
        PUSH       AX
        MOV        AL,0DH            ;CARRIAGE RETURN
        CALL       DISPCHAR
        MOV        AL,0AH            ;LINE FEED
        CALL       DISPCHAR
        POP        AX
        RET                          ;RETURN TO PHONE DIALING ROUTINE
CR--LF ENDP
;
;
START1 ENDP
CODE ENDS
        END        START1
```

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