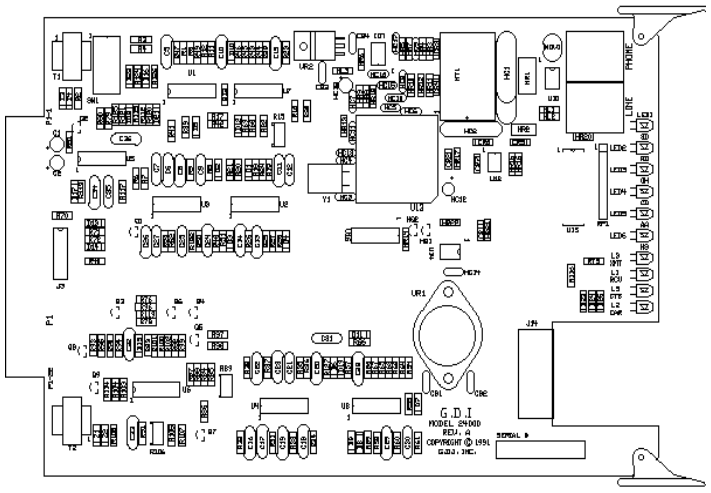
Model 24004

DUAL MODEM



GDI

Sunnyvale **General Devices and Instruments** ***Inc.***

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INTRODUCTION

The GDI Model 24004 is a combination of two modems on a single card that plugs into the Model 170 modem slot. One modem is the functional equivalent of a Model 404 private wire 2400 baud modem. The other is a versatile, "Hayes" compatible, dial-up modem, capable of speeds up to 2400 baud.

The GDI Model 24004 provides a high performance alternative to consumer grade "external" modems in "Field Master" applications. It is ideally suited for use with newer 170 controller specifications such as the 170SC, 170E and 170A.

FEATURES

- A "Model 404" and a "Hayes" modem on one card.
- Eliminates external modem in 2400 baud systems.
- Front edge mounted status indicators.
- Industry standard 'AT' command set.
- Highly flexible configuration options.
- Fully temperature tested.
- Configuration stored in NVRAM - no jumpers.
- Low Power Operation

GENERAL SPECIFICATIONS

Form Factor
Standard Model 400

Current Requirements (Typical)
200 mA (+12V)
100 mA (-12V)

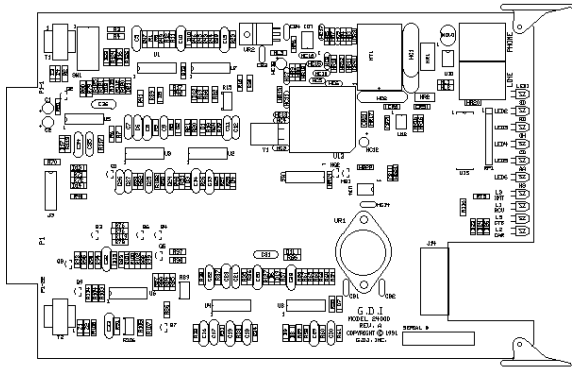
Environmental Operating Ranges

Temperature	-37 to +74°C
Humidity	95% (non-condensing)

Preparing the "Model 404" Section

The "Model 404" section is shipped from the factory to operate in FDX (4-wire) mode with standard timing characteristics. Should the application require HDX (2-wire) operation, or different timing characteristics, it is necessary to reset the DIP switch (SW1) according to the following:

SW1 Location
⇓



⇑
J14 Location

```
                                                1 2 3 4 5 6 7 8
Full/Half Duplex _____________________________|_| | | | | | | |
on/off - full duplex                            | | | | | | | |
off/on - half duplex                            | | | | | | | |
                                                | | | | | | | |
Request to Send - Clear to Send Timing _____|   | | | | | | |
off - 12±2 mSec                                 | | | | | | |
on  - 6±2 mSec                                  | | | | | | |
                                                | | | | | | |
Carrier Turnoff (Soft Carrier) Timing _________|  | | | | | |
off - 10±2 mSec                                 | | | | | | |
on  -  5±2 mSec                                 | | | | | | |
                                                | | | | | | |
Local Echo enable/disable_____________________|  | | | | | |
off-local echo enabled(required for FDX)        | | | | | |
on-local echo disabled (normal for HDX)         | | | | | |
                                                | | | | | | |
Receiver Squelch Timing_____________________________| | | | |
(Half duplex, local echo disabled)                  | | | | |
off - 6.5±1 mSec                                    | | | | |
on  -   3±1 mSec                                    | | | | |
                                                    | | | | |
Receive Line Signal Detector Timing_________________| | | | |
(Carrier Detect Timing)                               | | | |
off - 8±2 mSec                                        | | | |
on  - 4±2 mSec                                        | | | |
                                                      | | | |
Not Used______________________________________________| | | |
```

SW1 Settings - 4 Wire, Full Duplex, Standard Timing							
1	2	3	4	5	6	7	8
ON	OFF	OFF	OFF	OFF	OFF	OFF	X

SW1 Settings - 2 Wire, Half Duplex, Standard Timing							
1	2	3	4	5	6	7	8
OFF	ON	OFF	OFF	ON	OFF	OFF	X

SW1 Settings - 4 Wire, Full Duplex, Fast Timing							
1	2	3	4	5	6	7	8
ON	OFF	ON	ON	OFF	ON	ON	X

Please note that to change timing parameters, switch positions 3,4,6, and 7 should be changed together. They should be all OFF or all ON. Also, if "Fast" timing is desired to reduce handshake time requirements, all "local" modems connected must support, and be configured for, "Fast" timing.

Preparing the "Smart" Section

The Model 24004 is shipped from the factory in a commonly used operating configuration, however, some software suppliers require different operating options.

Some "Field Master" software automatically configures the smart section by sending it an initialization string. This makes preparation of the smart section unnecessary.

Other software suppliers do not initialize the smart section, and expect it to operate in a predetermined manner. In this case, you must manually configure the modem before installation. Use the following procedure to manually configure the smart section when required by your software supplier.

Material Required:

1. Dumb terminal or computer with terminal emulation software.
2. Cable to interface terminal device to modem. (DB-9S to DB25S)
3. 170, 170A, 170E, or 170SC traffic controller with open modem slot.
4. Documentation for "Field Master" software and controller.

Procedure:

1. Configure terminal device to the same baud rate and character format used by the "Field Mas-

ter" when communicating with the smart modem. Consult documentation.
2. Carefully remove the jumper arrangement (J3) from its socket (close to edge connector). This disconnects the "Smart" section from the edge connector.
3. Connect interface cable between the terminal device and J14.
4. Install modem in modem slot of controller.
5. Power up terminal device and controller.
6. Type modem initialization string (consult documentation) followed by (return). If string does not end with the characters "&W", type "AT&W" (return).
7. Replace the jumper arrangement (J3).

INSTALLATION

Installation: 170 - with C20 option

The standard Model 170 does not support 2400 baud operation without modifications. Therefore, it may be beneficial to consider the use of the GDI Model 24000. The 24000 combines a "Hayes" compatible modem with a Model 400 1200 baud modem.

The Model 24004 plugs into the modem slot of the 170 controller. The "Model 404" section of the card will operate in exactly the same fashion as a Model 404.

You must connect the "smart" section to the auxiliary ACIA in one of two ways:

1. Connect serial cable between J14 and controller C20.
2. Modify motherboard to connect ACIA2 to edge connector.

Option 1 is the simplest solution, but requires an additional cable exit from the front of the controller. Option 2 eliminates the need for a serial cable, but requires a controller mod.

Installation: 170A, 170E, 170SC

The Models 170A Dual ACIA, 170E Dual ACIA, and the 170SC Quad ACIA offer two advantages over the standard Model 170. The first is that all modem slots support the dual modem pin-out. This allows the use of dual modems (like the Model 24004) without a C20 cable. The second is that each ACIA baud rate is independently adjustable (by jumpers), and includes a 2400 baud option, ideal for use with the Model 24004.

Set the baud rate for both ACIA's to 2400 baud (consult controller documentation).

The Model 24004 plugs directly into the modem slot. In the case of the 170SC Quad ACIA, the primary modem slot is normally used.

Installation: Phone Line Connection

The last installation step is to connect the phone line to the RJ11 jack "LINE". The jack marked "PHONE" is for an optional handset. Make sure to route the phone line so that it is not pinched or abraded when you secure the front panel. Make a notch if needed.

Note: If you would like to temporarily connect a data terminal to the smart section through J14 for testing purposes, disconnect the controller from the modem by removing the jumper arrangement plugged into J3 (close to edge connector). Don't forget to put it back!

SMART MODEM SECTION

Specifications

Compatibility
CCITT V.22 bis 2400 baud
CCITT V.22 1200 baud
Bell 212A 1200 baud
Bell 103 300 baud
Automatically Adapts to calling or called modem.

Serial Data format
Character Asynchronous
7 data bits with any parity type + 1 or 2 stop bits.
8 data bits with Mark or No parity + 1 or 2 stop bits.

Line Requirement
Public Switched Telephone Network

Line Interface
Meets FCC Part 68 requirements
Max. Transmit Level -9dbm (600Ω)

2-Wire full duplex (TIP and RING)

Modes of Operation

Asynchronous
Full or half duplex
Automatic and manual call originate
Automatic and manual call answer

Modulation

V.22 bis - Quadrature Amplitude Modulation (QAM)
V.22 and 212A - Differential Phase Shift Keying (DPSK)
V.21 and 103 - Frequency Shift Keying (FSK)

Transmit Carrier Frequencies

V.22 bis:
V.22:
212A: ORIGINATE 1200 Hz +/- 0.01%
ANSWER 2400 Hz +/- 0.01%

Bell 103:

ORIGINATE 'space' 1070 Hz +/- 0.01%
ORIGINATE 'mark' 1270 Hz +/- 0.01%
ANSWER 'space' 2020 Hz +/- 0.01%
ANSWER 'mark' 2225 Hz +/- 0.01%

Line Equalization

(a) Fixed compromise equalization in transmitter
(b) Adaptive equalizer for 1200 and 2400 bps in receiver

Receive Carrier Detect

Off-to-On Threshold: -43 dbm
On-to-Off Threshold: -48 dbm
Hysteresis: Greater than 2 dB

Serial Interface Signals

RS232C/V.28 levels with CCITT V.24 protocols

NVRAM

Allows storage of two user profiles and four 36-digit dial strings. Eliminates switches and jumpers.

Command Set

Industry Standard Hayes "AT" 2400B and 2400

Equalization

(a) Fixed compromise equalization in transmitter
(b) Adaptive equalizer for 1200 and 2400 bps.

Performance

Bit Error Rate <1:10^5 for a S:Noise Ratio of 10dB
TxD Level -10 dbm
RxD Level -45 dbm

Indicators

Indicators for SD, RD, OH, CD, AA, and HS
Mounted on front edge of PCB

Timing

Carrier Detect Response Time
100 mSec - 25.5 Sec (default 600 mSec)

Controller Interface

EIA RS-232C via edge connector or 9 pin Male D-Sub connector J14, user selectable.

J14 Pinout (9 Pin Male RS232)

Pin	Function	Direction
1	DCD (Data Carrier Detected)	Output
2	RXD (Received Data)	Output
3	TXD (Transmitted Data)	Input
5	GND (Signal Ground)	Common
6	DSR (Data Set Ready)	Output
8	CTS (Clear To Send)	Output

170 Edge Connector Pinout

Pin	Function
A & B	Signal common (DC Ground)
C & D	+12 Volts
E & F	-12 Volts

(The following may be disabled by removing Jumper J3)

9	DCD (Data Carrier Detected)
11	TXD (Transmitted Data)
12	CTS (Clear To Send)
13	RXD (Received Data)
15	DSR (Data Set Ready)

Telco Connector Pinout (LINE)

Pin	Function	Direction
4	TIP TERMINAL	To/From RJ11C jack
3	**RING TERMINAL**	**To/From RJ11C jack**

Adjustments

NVRAM

The "Smart" Section of the Model 24004 is equipped with **N**on **V**olatile **R**andom **A**ccess **M**emory. This memory stores modem operating parameters even when power is off. Two complete User Profiles and four Dialing Strings may be stored. This eliminates the need for jumpers while allowing more flexibility. Initializing this memory for your application is covered in the "Preparing the Smart Section" portion of this manual. A detailed description of which parameters are stored in this memory and how to alter its contents is given in the "Command Set" section.

Theory of Operation

System Description

In the "Drawing Appendix" of this manual is a Block Diagram and a Schematic of the Model 24004 "Smart Section". It may be useful to the reader to refer to these drawings during the "Theory of Operation" discussions.

From a system perspective, the "Smart" modem has three interfaces with the outside world.

1. Power Supply — Edge Connector P1
2. RS-232 — Edge Connector P1 or J14
3. Phone Line — RJ11-C Connector "LINE"

All power required by the modem is derived from the ± 12 Volts DC supplied by the controller at the modem edge connector.

Modem commands, responses and data are exchanged with the controller in a serial (RS-232) format through either the edge connector or J14.

Phone line connections are made by a modular RJ-11 jack marked "LINE".

Detailed Circuit Description

The GDI Model 24004 consists of 6 functional blocks. They are the power supply section, the DAA (Data Access Arrangement), Hybrid Section, Integrated Modem, NVRAM, and the Interface section. The following paragraphs describe their operation.

Power Supply

The power supply section derives all voltages necessary for operation. The voltages required on the Model 24004 board are +12, -12, +5, and -5 volts. The ±12 volt supplies are obtained through the edge connector of the Model 24004. VR1 regulates the +12 volts to produce +5 volts. VR2 regulates the -12 volts to produce -5 volts.

DAA (Data Access Arrangement)

This is the telephone line interface. Its functions are:

1. Comply to impedance and isolation requirements (FCC part 68).
2. Furnish a method of switching between the modem and an optional telephone handset.
3. Provide for on/off hook control as well as pulse dialing.
4. Ring detection.

The FCC has stringent rules regarding the characteristics of devices connected to public telephone networks. These are detailed in Part 68 of the Code of Federal Regulations. Transformer T1 presents the proper impedance to the telephone line while isolating the TIP and RING signals from the hybrid. Opto-coupler U12 is the isolating element of the ring detector subsection of the DAA. Opto-Relay U10 allows isolated switching of the phone line between the modem and an optional handset. Relay U10 also allows isolated on/off hook control and a mechanism for pulse dialing.

Hybrid Section

The hybrid portion of the modem performs 4-wire to 2-wire conversion, receive prefiltering and transmit post-filtering. It includes dual op-amp U11 and associated discrete components.

The Integrated Modem handles transmitter and receiver functions independently. This makes 2-wire to 4-wire conversion necessary. The hybrid accomplishes this by essentially "subtracting" transmitted components from the receiver. Also, the Hybrid performs First Order signal filtering.

Integrated Modem

The Integrated Modem (RC224AT/1 U13) is the heart of the "Smart" section of the Model 24004. It is a self-contained microcontroller and digital signal processor on a single CMOS chip.
Integrated Modem Functions:
1. Perform complex receive and transmit filter functions.
2. Synthesize transmitted signals.
3. Analyze and execute commands.
4. Control and monitor DAA.
5. Support NVRAM.
6. DTE handshaking functions.

Filter functions are performed internally using DSP (Digital Signal Processor) techniques. Transmitted signal synthesis is achieved using digital to analog conversion techniques. An internal oscillator in conjunction with crystal Y1 furnishes the master timing source. The RC224AT/1 also has an internal high speed 16 bit microcontroller. Its program, contained in internal masked ROM, controls all modem functions. It is a self contained, single chip, device that needs only a clock and power to operate.

NVRAM

NVRAM stands for **N**on **V**olatile **R**andom **A**ccess **M**emory. Its purpose is to retain important configuration options even while power is off. This design uses a serial device (93C46 U14). The system controller (U3) modifies the contents of this device according to software configuration commands (&Wn).

Interface

The Interface Section provides level conversion (TTL to RS-232), connection options, and status indicators. U15 buffers signals from the Integrated Modem to drive status indicators. Transistor HQ1 converts TXD (RS-232) to TTL levels while U8 is an RS-232 line driver (1488). J3 is a shunt arrangement that, when removed, 'disconnects' the "smart" modem from the edge connector (P1). This option is useful when cable connection (through J14) is desired (see INSTALLATION).

Maintenance

Preventive Maintenance

The "smart" section requires no preventive maintenance.

Alignments

The "smart" section of the Model 24004 is self aligning using a technique called adaptive equalization.

Trouble Analysis

The GDI Model 24004 is tested over temperature before shipment, however, rare circuit failures do occur for a variety of reasons. Troubleshooting Flowcharts and Test Procedures are included to aid in fault isolation. Also, please note that, many "problems" are caused by improper connections and/or noisy phone lines.

Trouble Analysis Special Considerations

All modems that connect to dial-up lines must conform to FCC part 68 regulations. This means that the manufacturer performs special testing to ensure compliance. For this reason GDI recommends that no attempt at repairing the DAA section of the modem should be made by the user.

Waveforms and Voltage Measurements

The "smart" portion of the modem is purely digital in nature. All logic signals conform to TTL standards. All serial I/O signals conform to RS-232 standards. Voltage measurements of the power supplies should be within 5% of nominal.

Test Procedure

The following test procedure is outlined as a minimum effort to ensure correct modem operation. It relies on a diagnostic capability of the modem called analog loopback in which the modem communicates with itself. More thorough testing requires highly specialized equipment and is beyond the scope of this document.

Equipment Required:
1. Dumb terminal or computer with terminal emulation software.
2. Cable to interface terminal to modem. (DB9-S to DB25-S)
3. 170 traffic controller with no cards installed.
4. Access to standard dial-up telephone line.

PREPARATION
1. Configure terminal device for 1200 baud, 7 data bits, 2 stop bits and even parity.
2. Connect interface cable between the terminal and J14.
3. Connect phone line to RJ11 jack "LINE".
4. Temporarily remove jumper J3.
5. Install modem in modem slot of controller.
6. Power up terminal.

BEGIN TEST
1. Power up controller observing LED's on front edge of modem. After modem initialization, the lamp labeled AA should be on. (If not, enter AT&FS0=1&W <return>.)
2. Enter ATS18=0&T1 <return> on the terminal. This enables the Local Analog Loopback mode.
3. The modem is now essentially connected to itself. Characters typed at the keyboard are sent through modulator and demodulator sections of the modem and returned to the terminal. Therefore characters seen at the terminal should be exactly those typed. Type a message with many different characters such as "the quick brown fox jumps over the lazy dog". Verify that what is seen on the screen is exactly what was typed. Verify that the lamp labeled CD is on and, while typing, the SD and RD lamps flash.
4. Type +++ <no return>. This should cause the modem to respond with "OK" and return to command mode.
5. Enter AT&T0 <return> ending the test. Modem should respond "OK".
6. Call the modem from a remote phone. The modem should answer the call (OH light on), respond with "RING" on the terminal, and you should hear a tone. After around 30 seconds the modem should hang up (OH light off) and respond "NO CARRIER".
7. Type ATDPn <return> where n is the phone number of the remote phone. The modem should go off hook and pulse dial the number. The remote phone should ring. Answer it! It's for you. You should hear nothing on the phone, but after around 30 seconds the modem will hang up and respond "NO CARRIER".

END OF TEST

COMMAND SET

The call setup and user option commands for the Model 24004 are compatible with the Hayes Smartmodem 2400. The following paragraphs explain the functional groups and the function of each of the user options. These options will configure the modem for the basic operating modes. The software commands are issued from an ASCII terminal in serial mode, or from a microcomputer through a UART or ACIA. These commands allow the user to personalize the modem to his or her environment. Two user 'profiles' may be saved in a Non-Volatile RAM.

Software Configuration Commands

This section lists all the Model 24004 codes, commands and registers, that may be used while configuring the "smart" modem. Commands instruct the modem to perform an action, the values in the associated registers determine how the commands are performed, the result codes returned by the modem tell the user about the execution of the commands.

The following paragraphs arrange the codes into functional groups. The commands are

of four basic types, dialing, answering, standard functions, and special functions.

The commands are entered in a string, with or without spaces. Any spaces within or between commands are ignored by the modem. During the entry of any command, the "delete" or "backspace" key can be used to correct any error. Upper case or lower case characters can be used in the commands. Some exceptions to this rule are mentioned in association with the specific commands.

All commands described in the following paragraphs refer to asynchronous terminals using ASCII codes.

(AT) Attention Code

The attention code, **`AT', begins every command line except A/.** AT may be entered as upper or lower case characters, and cannot be deleted using backspace or delete keys. More than one command can be placed on a single line and separated with spaces for readability. The command line must end with the ASCII character stored in S Register 3, which defaults to decimal 13 (Carriage Return). A line with no carriage return is ignored. Commands following the AT are processed after receiving the carriage return character. **This attention code is used by the modem to detect the bit rate and character format of the connected DTE.**

(A) Answer Command

This command causes the modem to go off-hook and take control of the telephone line (in answer mode), from the telephone set. After receiving this command the modem cannot accept any more commands, as it immediately answers the call and goes into the data mode. While in the data mode the Escape code (+++) will return the modem to the command mode. This command is useful for manually answering a call.

(A/) Repeat Command

The repeat command instructs the modem to repeat the execution of the last command line stored in the command buffer. **This command is neither followed by carriage return, nor preceded by the attention command AT.** The previously executed command remains in the command buffer until an AT is entered or power is removed from the modem. Both actions clear the buffer and make the A/ command invalid since there is no command to repeat. The repeat command can be used to re-dial a number if busy.

(Bn) BELL/V.24 Protocol Compatibility

The B command selects the protocol for 1200 bps operation between CCITT and Bell modes. The command is ignored when the modem operation is at 300 or 2400 bps. B0 sets the modem to CCITT mode V.22 bis. The default B1 sets the modem to Bell mode 212A.

CCITT mode V.22 bis sends 2100 Hz for 3.3 seconds and 75 mSec of silence followed by unscrambled ones in the answer mode, while the BELL 212A protocol simply sends 2225 Hz.

The transmitted signal in the originate mode sends scrambled ones at 1200 bps for both V.22 bis and Bell 212A.

(Cn) Carrier Control Option

This command is reserved for a future controlled carrier mode. C0 will cause an ERROR result code. C1 (default) will return OK.

(Dstring) The Dialing Commands

The Dstring command causes the modem to go off-hook and dial a phone number defined by 'string' (auto-dial mode). The characters that may be included in 'string' are:

```
Digits 0 to 9          (pulse or tone)
A to D, "*" "#"     (touch tone only)
";" "," "@" "!"      (dial modifiers)
P, R, T, W           (dial modifiers)
S=n          (stored string - see &Zn)
```

Punctuation (parentheses, hyphen, and spaces) entered within 'string' for readability is ignored.

P,T These modifiers select between Pulse and Tone dialing for the succeeding digits to be dialed.

, The comma causes the modem, while dialing, to pause for the time specified by register S8 (default is 2 seconds). This delimiter is used, for example, to pause between dialing an external access code from a PBX, and then dialing the desired number. Multiple commas may be used.

; The semicolon placed at the end of a dial command places the modem in command state after dialing. It does not provide connection with another modem, but holds the line for further commands. The modem asserts that it has finished dialing by returning the result code `OK'. This command is useful in dialing long numbers.

@ The @ modifier causes the modem to look for a line signal followed by 5 seconds of silence before going to the next symbol in the dialing 'string'. Register S7 determines the maximum wait time. If quiet answer is detected, the subsequent dialing symbols are executed. If busy is detected instead of dial tone, the modem returns a BUSY result code and goes on-hook, abandoning the rest of the command line. S7 default is 30 seconds.

! The flash command causes the modem to go on-hook for .75 second. Flash might be used for transferring calls.

S,S=n Dial string stored in NVRAM (See &Zn=string). ATDS will dial stored string 0. ATDS=n will dial stored string n where n is 0 through 3.

R The Reverse command at the end of dialing permits the establishment of a call in reverse mode, i.e., the local modem, which originated the call enters the `answer' mode. This is a useful command for communicating with an `originate only' modem at a remote site.

W Causes modem to Wait for a dial tone before dialing. Register S7, which is also used for the "@" modifier, determines the amount of time the modem will wait for a dial tone before dialing. If a busy signal is detected, the modem hangs up, returns a BUSY result code, and abandons the rest of the 'string'.

(En) Echo Command

The Echo command determines whether the modem will echo the characters sent to it while in the command state. E1 causes the modem to echo, which is the system default, and E0 sets the modem to no echo.

(Fn) On-Line Echo

The Fn command is reserved for a future on-line echo option. F0 returns an ERROR result code, F1 returns OK.

(Hn) Switch Hook Control

The H or H0 (default) command causes the telephone line relay to disconnect (hang up). The H1 command will cause the telephone line relay to go off-hook.

(In) Request Product Code and Checksum

The I command requests the product code. The Model 24004 will respond with 24x where x is the software revision level. The command I1 causes a checksum to be computed on the internal ROM and returned as four ASCII numeric characters followed by a carriage return, line feed. The I2 command performs a checksum with a response of OK or ERROR. I3 returns a part number and revision level.

(Ln) Speaker Volume

Reserved for future implementation that incorporates a call-progress monitor speaker. Modem will return OK for n=0,1,2,3.

(Mn) Monitor Speaker On/Off

Reserved for future implementation that incorporates a call-progress monitor speaker. Modem will return OK for n=0,1,2,3.

(On) On-Line

The O command returns the modem to the on-line mode, after temporarily bringing it to the command mode by using the escape code (+++). O1 causes the modem to return to the on-line state and initiate a retrain sequence (2400 bps only). Issuing an ATO from an off-line idle state causes a "NO CARRIER" response. ATO issued from the call progress mode (after an "ATDxxxxx;" which puts the modem in a command state after dialing) causes the modem to remain in the originate mode.

(Qn) Result Codes

The Q command turns on and off result codes during execution of commands. The code Q0 (default) enables result codes. When set to Q1, the modem will not return result codes. S Register values, identification codes, checksum results, and results of test modes with self tests are returned.

(Sn) Define S Register Pointer

Sn sets an internal pointer to a particular S Register, where "n" is the number of the register. Until another register is pointed to, the value of register "n" can be read with AT? and changed with AT=. n=0-27.

(Sn) Direct Register Commands

Sr?	Returns current decimal value of S register r.
Sr=n	Writes the 8 bit binary equivalent of n (0-255 decimal) to S register r.

Modem configuration variables are kept in 8 bit storage elements called "S registers". Some registers are dedicated to one function while others share the 8 bits to store information about the status of different commands (bit mapped). For an intelligent 'Host', it may be easier to directly write the desired data into the S registers rather than going through the longer process of stepping through each command. Understanding these registers allows the user to configure the modem at any time, and to change only the desired parameters. n=0-27.

(Vn) Verbal/Numeric (Verbose/Terse)

The Vn command selects the type of result codes returned by the modem after or during the execution of commands. V1 selects word result codes (default). V0 selects digit result codes.

Result Codes Returned by Modem		
Meaning	Short Form	Long Form
Command line executed without error	0	OK
Connected at 300 bps	1	CONNECT
Phone line ringing	2	RING
Carrier lost or never received	3	NO CARRIER
Command line error or line length exceeds buffer size	4	ERROR
Connected at 1200 bps	5	CONNECT 1200
No dialtone received within timeout	6	NO DIALTONE
Called line busy	7	BUSY
No answer within timeout	8	NO ANSWER
Connected at 2400 bps	10	CONNECT 2400

Long form results are preceded and terminated with both carriage return and line feed characters. Short form codes are only terminated with a carriage return.

(Xn) Enable Extended Result Code

Forms of this command can have an effect on Long Form CONNECT messages, Dialing (Blind or Wait for Dial Tone), and BUSY detection. 'Blind' dialing means that the modem goes off-hook and waits a time period specified by register S6 before dialing regardless of the presence or absence of dial tone. Wait for Dial Tone dialing means that the modem goes off hook and waits the time period specified by register S6 to receive a dial tone before dialing. If no dial tone is received within the allotted time, the modem returns NO DIALTONE.

X or X0	Connect Message	CONNECT
	Dialing	Blind (set S6 before dial)
	Dial Tone Timeout	No
	Busy Detection	No

X1	Connect Message	Full Message
	Dialing	Blind
	Dial Tone Timeout	No
	Busy Detection	No

X2	Connect Message	Full Message
	Dialing	Waits for Dial Tone
	Dial Tone Timeout	Yes - 5 seconds fixed
	Busy Detection	No

X3	Connect Message	Full Message
	Dialing	Blind
	Dial Tone Timeout	No
	Busy Detection	Yes (returns "BUSY")

X4 Default	Connect Message	Full Message
	Dialing	Waits for Dial Tone
	Dial Tone Timeout	Yes - 5 seconds fixed
	Busy Detection	Yes (returns "BUSY")

(Yn) Enable Long Space Disconnect

Y or Y0 (default) disables this option. Y1 sets the modem to disconnect when a space of 1.6 seconds or more is received from the remote modem. Also, under Y1, a space of 4 seconds is sent prior to going on-hook upon receiving a H0 command or detecting an ON to OFF transition on DTR if &D option is selected.

(Zn) The Reset Command

This command causes a reset and a recall of the profile that was saved in NVRAM by the &Wn command and then returns 'OK'.

Valid forms: ATZ or ATZ0 - recalls profile 0
ATZ1 - recalls profile 1

Any subsequent characters in the command line will be ignored.

(+++) The Escape Code

The escape code returns the modem to the command state from the online state, without releasing the telephone line. This command consists of an escape guard time (S12 default 1 second) and an escape character (ASCII code in S2 default '+'). The escape character must be is-

sued three consecutive times with a guard time before and after the characters. If the sequence is successful, the modem responds 'OK' and enters an 'escape' command state.

(&Cn) DCD Options

&C or &C0 (default) maintains a DCD ON condition and ignores the actual state of the data carrier from the remote modem. &C1 causes DCD to reflect remote carrier status.

(&Dn) DTR Options

DTR (Data Terminal Ready) is not provided by the Model 170. For this reason, DTR is wired internally to be constantly asserted (ON). &D or &D0 (default) causes the modem to ignore DTR. &D1, &D2 and &D3 return "OK" but have no effect on modem operation.

(&F) Fetch Factory Configuration Profile

Configures modem with defaults contained in ROM. This is the easiest way to initialize the modem into a known state. This command does not modify NVRAM (see &Wn). The following is a list of conditions following the &F command.

Auto answer disabled
Ring counter set to zero
Escape code character 43 (+)
Carriage return character 13 (carriage return)
Line feed character 10 (line feed)
Backspace character 08 (backspace)
Wait for dial tone is 2 seconds
Wait for carrier after dialing is 30 seconds
Pause Dial Modifier (comma) is 2 seconds
Carrier detect response time is 600 mSec
Lost carrier to hang up delay is 1.4 seconds
DTMF (touch tone) Duration/Spacing is 95 mSec
Escape code guard time is 1 second
Test timer set to zero
Minimum DTR pulsewidth is 50 mSec
Bell 212A at 1200 bps
Command echo on
Dialing mode will default to pulse
All Result Codes enabled
Full word Result Codes
Long space disconnect disabled
BUSY detect
NO DIALTONE detect
Wait for dial tone before dialing
DCD always on
DTR is ignored
Guard tones disabled
Pulse dial make/break ratio 39/61 (USA)
DSR always ON
Will grant remote digital loopback request

(&Gn) Guard Tone Options

&G or &G0 (default)	no guard tone
&G1	550 Hz guard tone
&G2	1800 Hz guard tone

(&Jn) Telephone Jack Selection

&J0 and &J1 commands are accepted by the modem but have no function. They are reserved for a future switching implementation.

(&Mn) Async/Sync Mode Selection

&M or &M0 (default) selects asynchronous mode. The &M1, &M2, and &M3 commands are reserved for future synchronous mode implementations. They will cause an ERROR response from the modem but will not affect operation.

(&Pn) Make/Break Pulse Dial Ratio

The make/break ratio for &P or &P0 is 39% make and 61% break, U.S. standard. The &P1 command sets the ratio at 33%/67%, compatible with the U.K. and Hong Kong.

(&Rn) RTS/CTS Options

The &Rn command is reserved for future RTS/CTS options.

(&Sn) DSR Options (Data Set Ready)

The &S or &S0 (default) command causes DSR to remain ON at all times while the modem has power. Command &S1 will cause DSR to operate in accordance with CCITT V.22 bis/V.22 recommendation.

(&Tn) Test Commands

The **&T0** command will terminate any test in progress. **The &Tn command should always be the last command in any command line.**

The **&T1** command will initiate Local Analog Loopback. This is used to verify the path which includes the local modem and the local data terminal equipment. &T0 can be used to terminate the test.

Test &T1 example:
S18 is the test duration timer

ATS18=0&T1	Test time of 0 allows the
the quick brown fox jumps...	User message
+++	Escape sequence
OK	Modem acknowledges +++
AT&T0	Ends test
OK	Test complete

The command **&T3** will initiate a Local Digital Loopback. This allows data being received from the remote modem to be looped back, in the digital section of the local modem, and sent back to the remote modem. This mode allows the remote modem to run a remote digital loopback test. Both modems must be connected before this test can start.

Test &T3 example:

+++	Escape
OK	Acknowledgment
ATS18=0&T3	Puts local modem in digital loopback
OK	Loopback mode

Operator performs tests from the remote modem at this point.

AT&T0	Terminate digital loopback
OK	Test ended

The command **&T4** (default) allows the modem to grant a request from the remote modem for a Remote Digital Loopback.

The command **&T5** prohibits the local modem from granting a request from a remote modem for a Remote Digital Loopback.

The command **&T6** is used to test the local data terminal equipment, remote and local modems, and the telephone circuit. The local modem sends a 'request for digital loopback' message to the remote modem. If conditioned, (see &T4,&T5) the remote modem will send back whatever it receives until the test is ended. Both modems must be connected before this test can start. Note: The &T6 command works at 1200 or 2400 baud only.

Test &T6 example:

+++	Escape
OK	Acknowledgment
ATS18=0&T6	Test started
the quick brown...	Test message
+++	Escape
OK	Acknowledge escape
AT&T0	End test
OK	Test complete

The command **&T7** starts a Remote Digital Loopback with Self-Test in accordance with CCITT Recommendation V.54. During the test phase, an internally generated data pattern of alternating ones and zeros at the selected bit rate is applied to the scrambler. An error detector capable of identifying errors is connected to the output of the descrambler. At the end of the test a three-digit error count from 0 to 255 is displayed. Both modems must be connected before the test can start.

Test &T7 example:

+++	Escape
OK	Modem Acknowledges
ATS18=0&T7	Start test
AT&T0	End Test
00	Zero errors
OK	Test acknowledgment

The command **&T8** starts a Local Analog Loopback with Self-Test in accordance with CCITT Recommendation V.54. During the test, an internally generated data pattern of alternating ones and zeros at the selected bit rate is applied to the scrambler. An error detector capable of identifying errors is connected to the output of the descrambler. At the end of the test a three-digit error count from 0 to 255 is displayed. If the modem is on line when the test starts, carrier will be lost. This test is useful for checking the local modem transmit and receive circuits.

Test &T8 example:

ATS18=0&T8	Start test
AT&T0	End test
000	No errors
OK	Acknowledgment

(&V) View Settings

The active and stored profiles are displayed (command status and S Register settings) along with stored telephone numbers. Inputs from the DTE are ignored while the view information is being sent to the DTE.

(&Wn) Write Configuration to NVRAM

The &Wn command saves a subset of the S registers in one of two User Profiles in NVRAM. &W or &W0 stores the current configuration in the first profile. &W1 stores current parameters in the second. One of the profiles (see &Yn command) is restored automatically whenever the modem is turned on, or upon issuing the Z or Z0 command. The second profile may be restored by the Z1 command. Registers saved are: S0, S14, S18, S21, S22, S23, S25, S26 and S27. Note: If the &Wn command is issued while in the escape state, an ERROR message will be returned,

and the current configuration will not be saved.

(&Xn) Synchronous Tx Clock Source

This command is reserved for selecting future synchronous mode transmit clock source.

(&Yn) Select Power Up Profile

This command determines which stored profile (see &Wn, Zn) is established upon modem power up. The selected &Y command will survive a power outage. &Y0 (default) restores profile Zero, &Y1 restores profile One.

(&Zn=string) Store Telephone Number

The &Zn=string command is used to store one of four (n=0,1,2,3) telephone numbers (into NVRAM) for dialing at a later time using the DS=n dial stored number command. 'String' represents an ASCII string composed of dial digits plus optional modifiers. Dial digits may include 0 - 9 (pulse or tone dial) and A,B,C,D,#,and * (tone only). Possible modifiers include comma,T,P,R,W,!,@, and ; as described in Dstring command. Up to 33 characters may be stored. Unrecognized characters such as space, dash, and parenthesis are ignored and need not be included in the count. If more than 33 recognized characters are supplied, the dial string will be truncated to 33. If the &Zn=string command is issued in the escape state, an ERROR message will be returned and no dial string will be stored. If parameter n= is omitted, 0 is assumed.

&Zn Example 1:

AT&Z T 555-1212 stores T5551212 into NVRAM location Zero.

OK	modem acknowledges
ATDS	dial stored string Zero
T5551212	modem acknowledges and dials

&Zn Example 2:

AT&Z2=T1(602)961-2997 stores T16029612997 into NVRAM location 2.

OK	modem acknowledges

The number stored by the preceding command may be dialed from the command state by:

ATDS=2	dial stored number in location 2.
T16029612997	modem acknowledges and dials

Configuration (S) Registers

The Model 24004 incorporates 8 bit storage elements; called **S Registers.** These registers contain information that control modem operating parameters. Some registers are associated with particular functions while others have groups of bits assigned to different functions. A subset of these registers may be stored in NVRAM (see &Wn). Rather than stepping through many discrete commands, the user may find it easier to modify modem operating parameters by writing directly to S Registers. The registers can be read by "Sr?" and written by "Sr=n," where n is the ASCII decimal value of the digit(s) to be written, and r is the register number to read or write. Example:

ATS0=1	Writes a one to S register zero (Allows modem to auto-answer on
ATS0?	Will display contents (decimal)

S0 - Ring to Answer

The contents of this register determines the number of rings that must occur before the modem will automatically answer a call. Allowable range is 0 to 255. Setting this register to 0 will disable auto-answer. Setting this register to n (non zero) will cause the modem to auto-answer on the nth ring.

S1 - Ring Count

S1 is incremented by one each time the modem detects a ring signal. S1 is zeroed if no rings occur over any eight second period.

S2 - Escape Code Character

This register holds the ASCII decimal value of the escape code character. S2 can be set to any value from 0 to 255, but values greater than 127, without an ASCII equivalent, will completely disable the escape function. If the &D1, &D2, or &D3 option is in effect, the modem will return to the escape command state on an ON to OFF transition of DTR. S2 default value: 43 (ASCII +)

S3 - Carriage Return Character

This register contains the ASCII decimal value of the carriage return or end of line character. This character terminates both command lines and result codes. Allowable S3 range is 0 to 127. S2 default value: 13 (ASCII carriage return)

S4 - Line Feed Character

This register stores the ASCII decimal value of the line feed character, which is output after the carriage return character, when the modem is returning word result codes. Allowable S4 range is 0 to 127. Default value: 10 (ASCII line feed, CTRL J)

S5 - Backspace Character

This register holds the backspace character. When the modem receives the character defined by this register, it performs these four steps: 1. Echo the backspace character. 2. Sends an ASCII space. 3. Sends the backspace character a second time. 4. Deletes the last character in the command buffer. A typical command line can be backspaced until the T of the AT is reached. If an attempt is made at backspacing over the T, the modem will echo the backspace character and send an ASCII "T", but will not delete the "T" from the command buffer. The backspace character should not be set between 33 and 126, the range of printable ASCII characters. Allowable S5 range; 0 to 32 and 127. Default value: 8 (ASCII back space, CTRL H)

S6 - Wait for Dial Tone

This register defines the maximum amount of time the modem waits after 'off-hook' before dialing. In all cases, the modem waits for a minimum of 2 seconds even if S6 is set to a lower value. Allowable S6 range is 0 to 255 seconds. The "wait for dialtone" call progress monitoring feature will override the value in S6 and dial the first digit upon detection of a dial tone. Default value: 2 (seconds)

S7 - Wait for Carrier after Dial

In originate mode, extended result code options X3 or X4 allow S7 to establish the time that the modem waits (after dialing) for the answering modem to go off-hook (ringback). Once the answering modem goes off-hook, the originating modem then uses S7 to determine how long to wait for a carrier before terminating the call. This could result in a total wait time (dial to connect) of up to twice the value in S7. In answer mode, S7 is used as an abort timer. When an answering modem goes off-hook, it sends a carrier and expects one in response. If no response is received before S7 has elapsed, the answering modem will terminate the call.

If leased line operation is selected S7 has no effect, and the modem will wait indefinitely for the carrier. The operators at each end of the leased line will have sufficient time to establish the connection. Default value: 30 (seconds)

S8 - Pause Time for the Comma Dial Modifier

Register S8 contains the pause time for the comma (,) in a dialing string. S8 range is 0 to 255 (seconds). Default value: 2

S9 - Not Used

S10 - Lost Carrier to Hang Up Delay

This register defines the duration between loss of carrier and the initiation of a disconnect sequence (if configured for loss of carrier disconnect). The unit of time is 100's of milliseconds (tenths of seconds). If S10 is set to 255, the modem will ignore carrier detect status and assume that the carrier is always present. Allowable val-

ues are 1 to 255. Any loss of carrier will result in a disconnect if register S10 is smaller than S9. The actual length of loss of carrier is the delta between S10 and S9. Default value: 1.4 seconds

S11 - DTMF Duration and Spacing

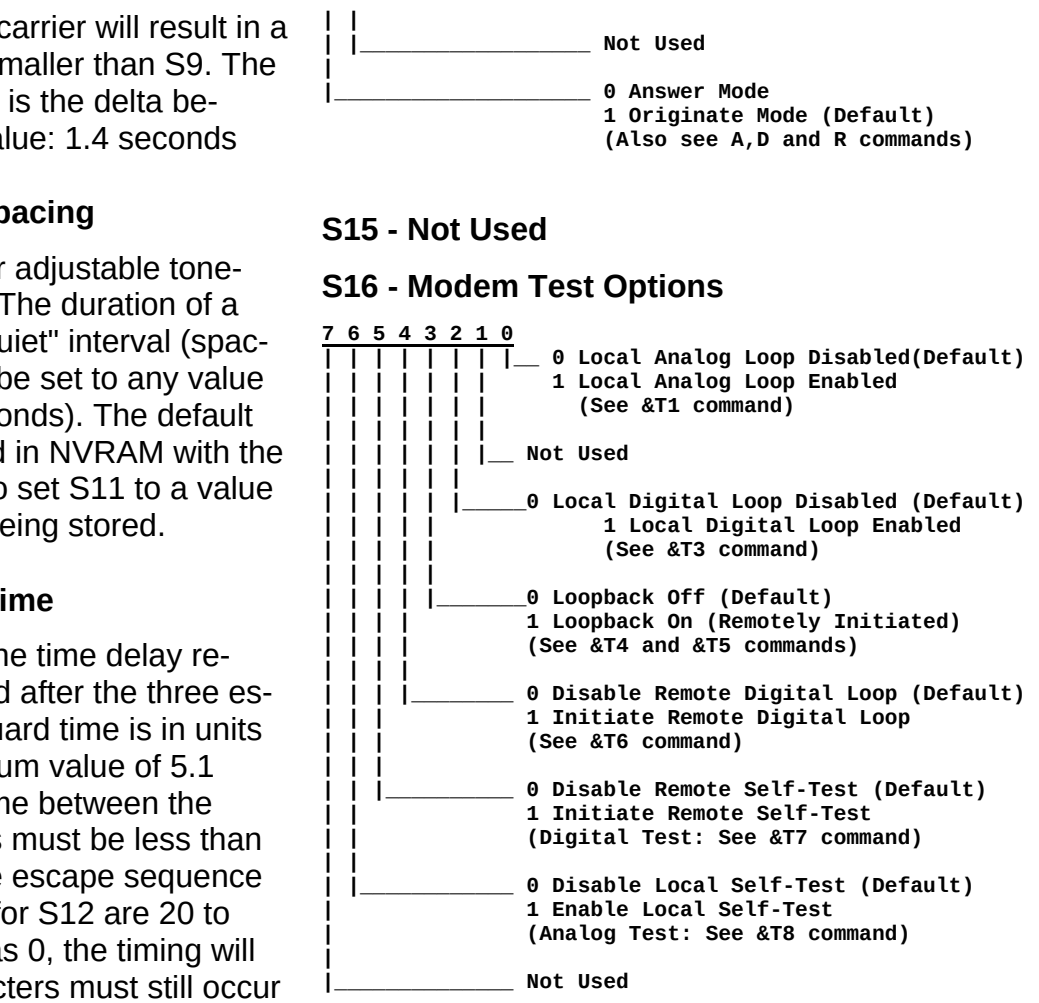
Register S11 allows for adjustable tone-dialing duration and spacing. The duration of a tone is always equal to the "quiet" interval (spacing) between tones. S11 can be set to any value between 50 and 255 (milliseconds). The default value is 100. S11 is not saved in NVRAM with the &Wn command. An attempt to set S11 to a value less than 50 will result in 50 being stored.

S12 - Escape Code Guard Time

This register controls the time delay required immediately before and after the three escape code characters. The guard time is in units of 20 mSec and has a maximum value of 5.1 seconds (255 * 20 mSec). Time between the three escape code characters must be less than the guard time in order for the escape sequence to be valid. Allowable values for S12 are 20 to 255. If guard time is defined as 0, the timing will not be a factor, but the characters must still occur consecutively. Default value: 1 second

S13 - Not Used

S14 - Bit Mapped Options



S15 - Not Used

S16 - Modem Test Options

This register not saved in NVRAM

S17 - Not Used

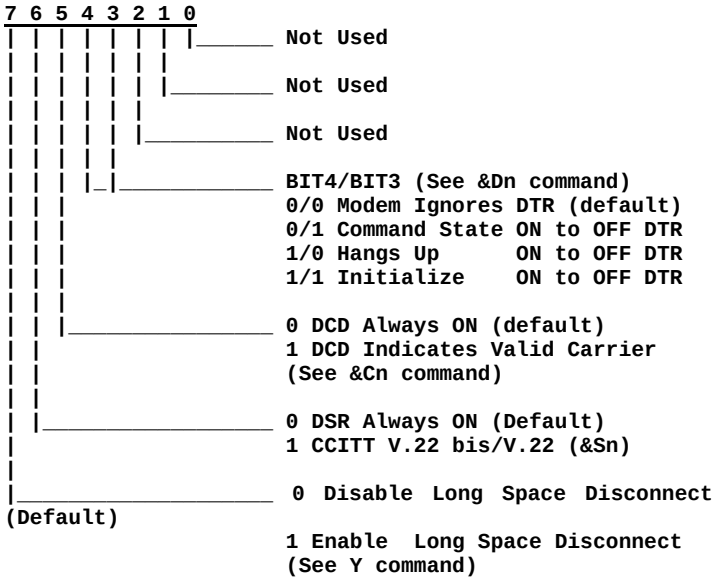
S18 - Test Timer

If S18 is set from 1 to 255 seconds, an &Tn command will time-out when this time has elapsed, automatically ending the test. &T0 will stop the test before S18 has counted down. If S18=0, tests will run continuously and &T0 must be used to end the test. Default value: 0 (continuous)

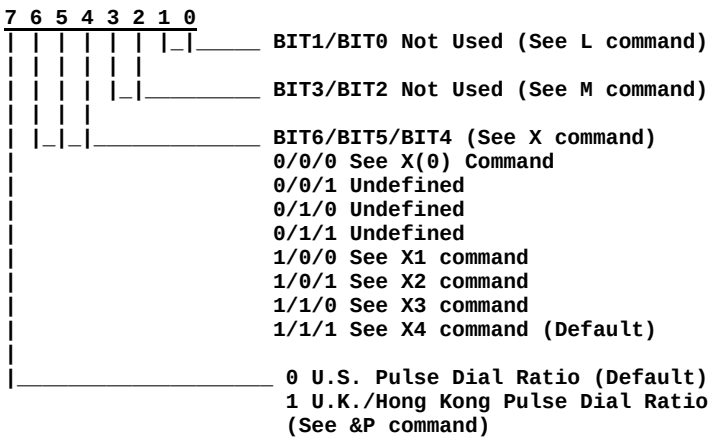
S19 - Not Used

S20 - Not Used

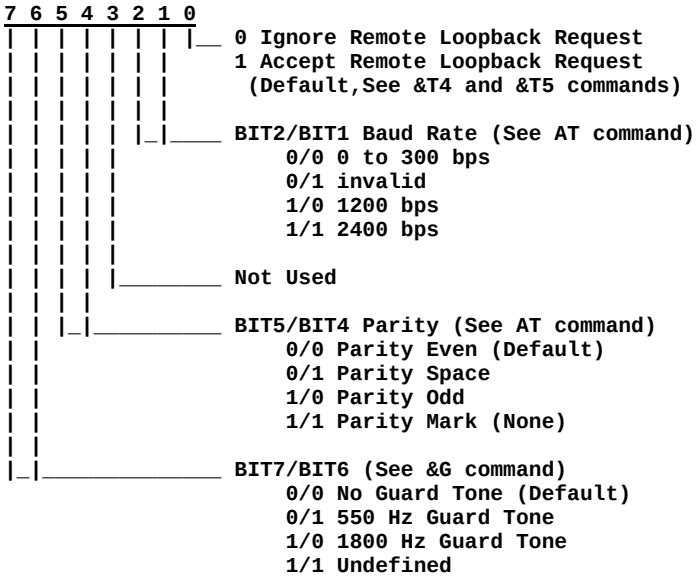
S21 - Bit Mapped Options



S22 - Bit Mapped Options



S23 - Bit Mapped Options



S24 - Not Used

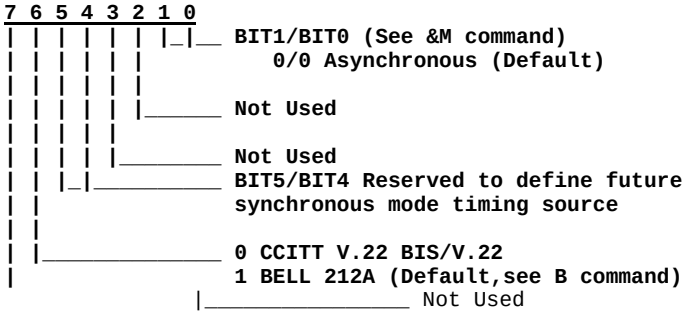
S25 - DTR Response Time

For DTR option &D1 this register specifies the amount of time DTR must be OFF in order to return the modem to command mode. For default &D0 (ignore DTR) mode this register is disregarded. S25 units are tens of milliseconds. Default value 5 (50 mSec)

S26 - RTS to CTS Delay Interval

Reserved.

S27 - Bit Mapped Options



Options Not Saved in NVRAM

```
Ring Counter ........................... 00
Escape Code Character .................. 43
Carriage Return Character .............. 13
Line Feed Character .................... 10
Back Space Character ................... 08
DTMF Duration/Spacing ............... 95mSec
Wait for Dial Tone ................... 2 Sec
Wait for Carrier after Dialing ...... 30 Sec
Pause, Comma Dial Modifier............ 2 Sec
Carrier Detect Response Time ....... 0.6 Sec
Lost Carrier to Hang Up Delay ...... 1.4 Sec
Escape Code Guard Time ............... 1 Sec
```

Options Saved in NVRAM (&W)

```
Bell/CCITT @ 1200 baud
Baud Rate ..................... 300,1200,2400
Parity ............ odd,even,mark,space,none
Answer on nth ring ................ 1 to 255
Auto-Answer ................... enable/disable
Command echo .................. enable/disable
Result Codes .................. enable/disable
Result Codes ................... verbose/terse
Dialing ........................ pulse/DTMF
Test Timer ................ 0 to 255 seconds
DTR circuit option
DCD circuit option
DSR circuit option
Long Space Disconnect ....... enable/disable
Pulse Dial Ratio
Grant/deny Remote Digital Loop
Guard tone option
Minimum DTR pulsewidth
```

Command Summary

AT Defines baud rate and precedes command line.

A/ Re-executes last command.

A Modem goes off-hook in answer mode.

B Sets CCITT V.22 operation when at 1200 bps.

B1 Sets Bell 212A operation when at 1200 bps.

Dstr Dial string following D in command line.

E Modem does not echo commands.

E1 Modem echoes commands back to terminal.

H Modem goes on hook (Hangs up).

H1 Modem goes off hook.

I Display product code.

I1 Display checksum of ROM.

I2 Validates internal ROM.

I3 Display ROM part number and rev. level.

O Return on-line.

O1 Return on-line with retrain.

Q Modem returns result codes.

Q1 Modem does not return result codes.

Sn Set S Register Pointer for AT? and AT=.

Sr=n Set register r to value n.

Sr? Display contents, S register r.

V Short numeric result codes.

V1 Full result codes

X CONNECT,result code enabled.

X1 CONNECT BBBB,codes enabled, blind, no busy detect.

X2 CONNECT BBBB, codes enabled, wait, no busy detect.

X3 CONNECT BBBB,codes enabled, blind, busy detect.

X4 CONNECT BBBB, codes enabled, wait, busy detect.

Y Long space disconnect disabled.

Y1 Long space disconnect enabled.

Zn Load profile n stored in NVRAM.

&C DCD always ON.

&C1 DCD ON if carrier present.

&D Modem ignores DTR.

&D1 Not used.

&D2 Not used.

&D3 Not used.

&F Load factory profile.

&G No guard tone.

&G1 550 Hz guard tone.

&G2 1800 Hz guard tone.

&P Pulse dial ratio U.S.

&P1 Pulse dial ratio UK/Hong Kong.

&S DSR always ON.

&S1 DSR compatible V.24.

&T0 End a test in progress.

&T1 Start local analog loopback test.

&T2 Not Used.

&T3 Initiate digital loopback.

&T4 Grants remote digital loopback request.

&T5 Denies remote digital loopback request.

&T6 Start remote digital loopback test.

&T7 Initiate remote digital loopback self-test.

&T8 Initiate local analog loopback self-test.

&V Display Active and Stored Profiles/Phone Numbers.

&Wn Write current configuration to NVRAM profile n.

&Yn Select Stored Profile on Power-Up.

&Zn Store phone number in NVRAM location n.

"MODEL 404" MODEM SECTION

Specifications

Data Rate and Format
0 - 2400 baud Serial Asynchronous, by bit

Modulation Type and Frequencies
Phase Coherent FSK
2400Hz/Mark, 4400Hz/Space

Line Interface
Dry, private wire. Maximum Distance 10 - 20 miles (depending on line facility and loading).
Characteristic Impedance - 600Ω

Receiver Characteristics
Dynamic Range - +3dbm to -45dbm
Carrier Detect Threshold -42±3dbm
Carrier Detect Hysteresis - ≈3dB
Demodulator Distortion <10% peak
(1200 bps, -40 dbm, 1:1 data pattern)
Receiver Frequency Tolerance - ±25Hz (for -40dbm)

Transmit Frequencies and Level
2400 Hz ± 1% - Mark
4400 Hz ± 1% - Space
1800 Hz - Soft Carrier
Factory Level Setting - 0dbm (600Ω)
Level Range: -8dbm to 0dbm (potentiometer)

Serial interface
Meets EIA RS-232C and CCITT V.24

Indicators
Transmit Data - XMT
Receive Data - RCV
Clear to Send - CTS
Receive Carrier - CAR

Timing (Switch Selectable)
RTS-CTS 6/12±2mS
CAR Delay 4/8±2mS
(Soft) Carrier Turnoff 5/10±2mS
Receiver Squelch 3/6.5±2mS

Mode Options (Switch Selectable)
2 wire Half Duplex or 4 wire Full Duplex

General FSK Modem Information

The term MODEM is a combination of two words, **MO**dulator and **DEM**odulator. Modems are designed to convert digital data into audio frequencies (Modulation) so that it can be transmitted over a telephone line. The audio data is then converted back to digital information by a modem on the other end of the telephone line (Demodulation). In this way, two digital devices (such as a data terminal and a computer) can be connected.

Modems can modulate digital information in several different ways. The "Model 404" portion of the Model 24004 uses a technique known as Frequency Shift Keying (FSK). Digital information is binary in format. That is, data is represented by either a logic high or a logic low (1 or 0). FSK modems generate a unique frequency for each logic level. The "Model 404" section generates two frequencies; 2400 Hz = logic low and 4400 Hz = logic high. Communications terminology refers to a logic low as a MARK and a logic high as a SPACE. By utilizing frequency sensitive filters, modems are capable of differentiating between MARK and SPACE frequencies in order to extract or demodulate received data.

The rate at which a communication line can change state is known as its baud rate. The baud rate can be interpreted as the equivalent of bits-per-second. The "Model 404" section is capable of communicating at baud rates up to 2400.

The "Model 404" section of this dual modem is capable of operating in either half duplex (HDX) or full duplex (FDX) mode. HDX operation implies that the modem can transmit or receive data, but that these actions cannot occur simultaneously. HDX is referred to as 2-wire mode. In FDX mode, the Modem can transmit and receive data simultaneously. FDX is known as 4-wire mode.

The "Model 404" section is shipped from the factory to operate in FDX (4-wire) mode with standard timings.

Theory of Operation

In the Drawing Appendix of this manual is a Block Diagram and a Schematic of the "Model 404" Section. It may be useful to the reader to refer to these drawings during the "Theory of Operation" discussions.

System Description

The "Model 404" section of the GDI Model 24004 operates in exactly the same fashion as a standard Model 404 modem. All signal and power connections are made through the modem edge connector as defined by the Model 170 specification. The following table describes pertinent signals.

"Model 404" Section Connections		
Signal Name	Pin	Function
DR (Data Receiver)	2	Modulated data input to modem (4-wire only).
DRR (Data Receiver Return)	3	Return circuit for DR
DX (Data Transmit)	X	Modulated data input/output (2-wire) or modulated data output only (4-wire).
DXR (Data Transmit Return)	Y	Return circuit for DX.
BA (Transmitted Data)	M	Digital data input to modem.
BB (Received Data)	P	Demodulated digital data output to controller.
CA (Request To Send)	L	Signals the modem that the 170 wants to transmit.
CB (Clear To Send)	N	Flags the 170 that the modem is ready to transmit.
CF (Carrier Detected)	K	Flags the controller that the sine wave which carries data is being received.
+12VDC	C&D	Positive power source.
-12VDC	E&F	Negative power source.
AA, AB (Ground)	A&B	Modem power and signal circuit common.

Circuit Description - Overview

As shown in the Block Diagram, data can enter the modem from three different sources, these sources being the Host Computer via DR (4-wire only) or DX (2-wire only), or the Users Terminal Transmitted Data (BA).

The digital data received by the modem from the Users Terminal (BA) will be modulated and driven out of the modem on the DX line (2-wire or 4-wire operation). If the modem is set up for HDX operation, the transmitted data will not be echoed back to the users terminal via the Received Data line (BB). In HDX operation the modem is capable of transmitting to TELCO or receiving from TELCO; however, these actions cannot occur simultaneously. When the modem is configured for FDX operation, it is capable of receiving and transmitting simultaneously (4-wire only). When Switch 1 is "ON" and Switch 2 is "OFF", data can be transmitted to TELCO (via DX) while simultaneously data from TELCO (via DR) is being forwarded to the users terminal via circuit BB, Received Data. In either FDX or HDX mode, data will always be sent to TELCO via the DX line.

Digital data from the users terminal enters on the Transmitted Data (BA) input. The data will be buffered from EIA RS-232-C levels and forwarded to an oscillator. The oscillator will output one of two frequencies (a third frequency is generated under special circumstances discussed later). If the digital data received is a logic low (MARK), the oscillator will output a 2400 Hz frequency. Should the input be a logic high (SPACE), the oscillator will output a 4400 Hz frequency. This "frequency shift" is how the modulator identifies a digital "one" (SPACE) from a digital "zero" (MARK). The modulated data is fed to a transmitter squelch circuit which will inhibit the transmission of data should the Request To Send (CA) be false (low). If Request To Send is true (high), the modulated data will be forwarded to a line driver and then impedance matched (via a Transformer) and driven out through the telephone wire on a line known as Data Transmitter (DX). The Request To Send logic will squelch the receiver section in HDX mode to insure that the transmitted data is not "echoed back" to the users terminal (dependent on the setting of Switch 5). This is the path for transmitted data in both HDX and FDX modes. When receiving data in the HDX mode, data enters the Data Transmitter (DX) input.

The received data is transformer coupled to a line receiver, filtered, limited, demodulated and presented to the users data terminal equipment on the Received Data (BB) output. In FDX mode, data enters the Data Receiver (DR) input. The data will then follow the same path as data received in HDX mode.

The users data terminal equipment will not receive data from the BB output unless the Carrier Detected logic has sensed the presence of a carrier. The logic is designed such that a MARK condition (2400 Hz) on the telecommunications line will enable the Carrier Detected circuitry. This circuit will latch and will remain active until either a sustained frequency outside of the receive filter passband or a line fault occurs. The modem is capable of generating a sustained frequency out of the normal receiver passband. When Request To Send goes false, the modem will alter the oscillator output from either 2400 Hz or 4400 Hz to approximately 1800 Hz, or less. This 1800 Hz signal, known as soft carrier, will flag the modem on the receiving end of the data stream, that communication has been suspended. Only the presence of a MARK condition on the telecommunications line in conjunction with a Request To Send (CA) signal will be able to reestablish the communications link.

Detailed Circuit Description

Carrier Reception, Detection, Demodulation

The presence of the carrier is detected in the same manner regardless of the mode of operation (i.e. HDX or FDX). Data received will be buffered by amplifier U1-d and then filtered by a two stage bandpass filter (U3-c,d). This filter network is designed to reject any frequencies which are outside of the carrier signal range. After the received signal has been filtered, it is boosted by amplifier U1-c and fed to a level detection circuit (U8 a,b,c). Amplifier U8-a is used at unity gain, driving Diodes D8 and D9 to create a "full wave" rectified voltage at the inverting input of amplifier U8-b. This DC voltage varies in relation to the strength of the receiver carrier signal. Low-pass amplifier U8-b filters this DC voltage and presents it to comparator U8-c. Whenever the rectified signal is greater than 6 VDC, U8-c will go high allowing C31 to charge through R67. At the end of a four millisecond charging period, comparator U7-a will be biased "ON". This "ON" condition will enable the Carrier Detected (CF) output as well as the Carrier LED (L2). At the same time this is occurring, the received data is also presented to a hard limiter (U1-b). The hard limiter circuitry establishes the input level to the demodulator circuitry. The demodulator consists of IC U2. amplifier stages U2-c,d filter out the SPACE frequency (4400 Hz) and convert it to a negative DC voltage through Diodes D1 and D2. The remaining sections of U2 filter out the MARK frequency (2400 Hz) and convert it to a positive DC voltage through Diodes D3 and D4. These DC outputs are summed at the input of the amplifier U7-c.

Amplifier U7-c acts as a lowpass filter to "clean-up" and amplify the output from the summing junction. This output is then fed through an additional four-stage, low-pass filter (IC U4) and presented to the EIA driver (IC U1-a) as well as comparator U7-d.

Comparator U7-d is biased such that when a MARK state is demodulated, the output of U4-d will force the inverting input of comparator U7-d to a level lower than the bias voltage on Pin 12 of U7-d. This forces the output high which reverse biases Diode D10. As long as the carrier frequency is present, U7-d will keep Diode D10 reverse biased. As long as the carrier is of sufficient amplitude, U8-c will keep Capacitor C31 charged through R67. Once the carrier frequency has been detected, comparator U7-a will forward bias Diode D12, thus changing the bias level on comparator U7-12. This effectively "latches" the carrier active unless the carrier amplitude goes too low or the modem receives an input frequency which is outside of the receive filter passband. Should the modem receive a signal out of its passband, the receive filter will reject the frequency, the output of U8-c will go low, and Capacitor C31 will discharge. This will cause the Carrier Detected (CF) line to go false (low). The absence of Carrier Detected will again change the bias to U7-d, which will forward bias Diode D10 and inhibit Carrier Detected until a signal of the correct amplitude and frequency is again received. The absence of Carrier Detected, disables the Received Data (BB) output of the modem.

Note that the Carrier Detected (CF) signal is affected by Switch 5. In HDX mode the pres-

ence of Request To Send is used to suppress the Carrier Detected (CF) signal (Switch 5 must be "ON"). As before, the suppression of Carrier Detected disables the Received Data (BB) circuit. This prevents transmitted data from being echoed back to the user. Referring back to the schematic, when the Request To Send line is true (high), Transistor Q1 will be "ON". This will bias comparator U7-b Pin-6 low resulting in a high output on Pin-7. A high on Pin-7 causes U5-9 to go high. This, in turn, causes U5-9 to go low, thus inhibiting Carrier Detected at comparator U7-3 (assuming Switch 5 is closed). Comparator U7-1 will be driven low. This will inhibit the EIA output of comparator U7 (BB).

Data Transmission

Data to be transmitted via the telephone line enters the modem on the Transmitted Data (BA) input. The data at this point is digital and will be at RS-232 levels. Assuming a SPACE state on the input (a logic high), Transistors Q7 and Q8 will be "OFF". These Transistors being "OFF", will effectively remove Resistors R86 and R93 from the oscillator circuitry (amplifiers U6-a,c,d). These amplifiers form a free running oscillator, which will oscillate at 4400 Hz (assuming Q7 and Q8 are "OFF") or at 2400 Hz if Q7 and Q8 are "ON".

The sine wave output from amplifier U6-a is fed to amplifier U6-b which acts as a line driver. This output is Transformer coupled (via T2) to the telephone line (DX). The output level of the transmitted signal is determined by Potentiometer R106. The frequency of the oscillator can be adjusted with Potentiometer R89.

In HDX mode, the transmitted data is fed not only to the outside world (via DX) but also goes to the receiver circuit (because Switch 2 is "ON"). The primary impedance of T2 is approximately 600 ohms.

This impedance, in conjunction with R108, forms a voltage divider which prevents the receiver from being overdriven. The data will follow the same receive path as described previously. The data will be buffered, filtered, limited, demodulated, and presented to the users terminal (assuming Switch 5 is "OFF"). This feature facilitates "loopback" testing. Under normal circumstances in HDX mode (Switch 5 "ON"), the transmitted data will disable the received data and the carrier detect outputs.

Modem Control

The most important control element of the "Model 404" section is the Request To Send logic. Before the user transmits data, he raises (activates) the Request To Send input.

The presence of Request To Send will turn Transistor Q1 "ON". This presents a logic low on the inverting input of comparator U7-b. Pin 5 of U7-b is biased at +6 VDC. The output of U7-b will then be a logic high, which reverse biases Diode D18. Capacitor C35 will charge through Resistor R115. This charging time will be approximately 12 milliseconds. During this 12 mSec charge time, the output of comparator U5-b (Pin-7) will be low. This allows the receiving modem 12 mSec to detect the presence of a carrier, prior to data being transmitted. The presence of Request To Send, will reverse bias Diode D17 (through comparator U5-a) thus enabling the output Line Driver U6-b. Should Request To Send go false, Transistor Q1 will turn "OFF", forcing U7 Pin-7 low. If Pin-7 is low, Diode D18 will be forward biased. This will cause C35 to rapidly discharge, thus dropping Clear To Send (CB) immediately. Also, if Pin-7 is low, Diode D16 will be reverse biased, and Capacitor C34 will discharge through R112. This will keep the Line Driver U6-b enabled for the period of time it takes C34 to discharge (approximately 8 mS). At the same time, because Request To Send went false (low), Transistor Q2 turned "ON". This will alter the frequency of the oscillator to 1800 Hz (soft carrier). The 1800 Hz signal will be transmitted to the telephone line, where it will be received by the remote modem. The remote modem will reject this frequency because it is outside of the receive filter passband range (2400 to 4400 Hz) and, therefore, will drop its Carrier Detected signal, signifying that the data transfer between modems has ceased.

Note that Request To Send could go false (low) when the data on the line is in SPACE con-

dition. This could cause problems as the oscillator is designed to output a 1800 Hz tone only if Transistors Q2, Q7 and Q8 are "ON". Remember that Q7 and Q8 are only "ON" during a MARK state. For this reason, whenever Request To Send goes false, Q6 is turned "ON" via R119 assuring a MARK state will exist independent of the BA input. Amplifier U5-a will ensure that the oscillator is enabled for the period of time it takes Capacitor C34 to discharge through R112.

For 2-wire mode only (Switch 5 "ON"), the Carrier Detected Disable line will be held active (low) while Request To Send is true (high), (i.e., while data is being sent). When Request To Send goes false (low), the Carrier Detected Disable line will be held active (low) for the period of time it takes to discharge C36 through R120 (approximately 7.6 mS). If an adequate incoming carrier is being received, the Carrier Detected condition will be achieved approximately 3.1 mS later (due to the charging of C31 through R67 at the input of comparator U7-a). Therefore, for HDX operation, data may be received by the modem approximately 11 mS after Request To Send goes false (low).

Alignments

There are three alignments that can be made to the "Model 404" section:

1. Transmit Level	R106	
2. Oscillator Frequency	R89	
3. Demodulator Symmetry		R15

Tools Required:

1. Frequency Counter
2. Slot Head Screw Driver
3. Oscilloscope
4. Square Wave Generator
5. AC RMS Voltmeter

Oscillator Frequency Adjustment

1. Apply Request To Send (CA High).
2. Transmit a SPACE (BA High).
3. Connect the frequency counter to P1-X (+), P1-Y (-).
4. Adjust R89 for 4400 Hertz indication.
5. Transmit MARK (BA Low).
6. Verify a 2400 +/- 5 Hz indication.

Demodulator Symmetry Adjustment

1. Set "Model 404" section to FDX mode.
2. Apply Request To Send (CA High).
3. Transmit a 1:1 bit pattern (2400 baud 50% duty cycle).
4. Interconnect P1-2 to P1-X and P1-3 to P1-Y.
5. Connect the Oscilloscope probe to P1-P (+), P1-A (-).

Adjust R15 for a symmetrical square wave indication.

Transmit Level Adjustment

1. Apply Request To Send (CA High).
2. Transmit a MARK (BA Low).
3. Connect a 600 ohm resistor between P1-X and P1-Y.
4. Connect the AC voltmeter to P1-X (+), P1-Y (-).
5. Adjust R106 for a 775 mV RMS (0 dBm) indication.

PARTS LIST

Description	Reference
24004 PCB (Revision A)	
CAPACITORS	
Capacitor, 47pf 50V	HC3
Capacitor, 56pf 50V	HC4
Capacitor,.47µf 250V	HC2
Capacitor,1.0 mfd 250V	HC1
Capacitor,.01mfd 50V	C28,C29,C30
Capacitor,.1mfd 50V polyester	C5, C10, C31,C34, C35, C36
Capacitor, .1 mfd 50V Monolithic Ceramic	CB1, 2, 3, 4, HC5, 6, 8,10,11, HC13, 14, 15, 16, 17
Capacitor, 10mfd 35V	C1,C2,HC12,HC18
Capacitor, 1000pf 50V	HC7,9
Capacitor,1800pfd 50V	C15,C21,C23,C32,C33
Capacitor,2200pfd 50V	C17,C19
Capacitor,4700pfd 50V	C6,C7,C8,C9,C11,C12, C13,C14,C16,C18,C20, C22,C24,C25,C26,C27
DIODES	
Diode, 1N4148	CR1,CR2,CR7,D1-19, D21-25
Diode, Zener 1N5229	CR3,CR4
Diode, Zener 1N5233B	Z1,Z2,Z3,Z4
Diode, Zener 1N5254	CR5,CR6
Clear Body RED LED (T1-3/4)	LED1 thru 6, L1,2,3,5
I.C. INTEGRATED CIRCUITS	
MC 3303	U2,U4,U5,U6,U7,U8
MC 33074	U1,U3
7805CK +5 VDC Regulator T03	VR1
7905 -5 VDC Regulator T0220	VR2
Modem Chip, RC224AT/1	U13
I.C. dual op amp, MC1558	U11
74HCT244 IC, Octal Buffer	U15
Opto-Coupler, H11A1	U12
MC1488 IC, RS232 Line Driver	U16
93C46 serial EEPROM	U14
LBA110 Opto-Relay	U10
POTENTIOMETERS	
1K CER MT	R15
2K CER MT	R89
20K CER MT	R106
SWITCHES	
8PST 8 POS DIP	SW1
TRANSISTORS	
2N3906	Q5
U1899 or J112 JFET	Q9
2N4401	HQ1,HQ2,Q1,2,3,4,6,7, 8
TRANSFORMERS	
42TL016 Audio Miniature	T1,T2
T-9312 Telephone Coupling	HT1
RESISTORS	
470 ohm SIP Resistor	RP1
604 OHM 1/4W 1% car film	R2,R40,R70,R108, R117,R49
resistor, 698 ohms 1% 1/4W	HR3
2.00K 1/4W 1% car film	R82,R85,R91
2.21K 1/4W 1% car film	R86,R93
2.32K 1/4W 1% car film	R81
2.43K 1/4W 1% car film	R52,R16
2.94K 1/4W 1% car film	R122
3.32K 1/4W 1% car film	R8
5.49K 1/4W 1% car film	R5
5.62K 1/4W 1% car film	R7
resistor, 13.0K 1% 1/4W	HR5
16.2K 1/4W 1% car film	R25
17.8K 1/4W 1% car film	R84,R88,R90
20.0K 1/4W 1% car film	R18,R20,R21,R24,R27, R28,R58,R59,R83
resistor, 22.1K 1% 1/4W	HR12
resistor, 23.7K 1% 1/4W	HR6
24.3K 1/4W 1% car film	R48
26.7K 1/4W 1% car film	R9
28.0K 1/4W 1% car film	R19, R26
31.6K 1/4W 1% car film	R4
34.8K 1/4W 1% car film	HR10
41.2K 1/4W 1% car film	R50
resistor, 43.2K 1% 1/4W	HR8
51.1K 1/4W 1% car film	R6
resistor, 66.5K 1% 1/4W	HR11
resistor, 68.1K 1% 1/4W	HR7, HR9
71.5K 1/4W 1% car film	R66, R127
80.6K 1/4W 1% car film	R67
84.5K 1/4W 1% car film	R51
100K 1/4W 1% car film	R124, R126
resistor, 110K 1% 1/4W	HR18
118K 1/4W 1% car film	R112, R120
140K 1/4W 1% car film	R53
158K 1/4W 1% car film	R125
169K 1/4W 1% car film	R115

1K 1/4W 5% car film	R57, R75
1.5K 1/4W 5% car film	R47
2.2K 1/4W 5% car film	R41, 69, 78, 98, 116, HR22
4.7K 1/4W 5% car film	R13, R71, R72, R76, R107, HR14 HR16,HR20,HR21
6.8K 1/4W 5% car film	R94
resistor, 8.2K 5% 1/4W	HR4
10K 1/4W 5% car film	R42, R63, R64, R79, R97, R99, R100, R102, R113, R119, R121
15K 1/4W 5% car film	R44,R95,HR2
27K 1/4W 5% car film	R22, R29, R30, R31, R32, R33, R34,R35,R36,R37
33K 1/4W 5% car film	R54,R55
47K 1/4W 5% car film	HR13, R1, R3, R11, R12,R17,R23,R43,R45, R60,R61,R62, R68,R80,R101
51K 1/4W 5% car film	R103
68K 1/4W 5% car film	R38,R96
100K 1/4W 5% car film	HR17, R46, R104, R105, R114
470K 1/4W 5% car film	R56,HR15
1meg 1/4W 5% car film	R39,R65,R87
resistor, 100 ohms 5% 1W	HR1
MISCELLANEOUS	
Card Ejector,RED	
Pin, Card Ejector	
Right Angle Telco Jack	PHONE,LINE
9 Pin Male Right Angle D-Sub	J14
16 Pin DIP Shunt	Plugs into J3
Varistor, V150LA2	MOV1
16 Pin IC Socket	J3
68 Pin IC Socket, PLCC	U13
12.000393 Mhz Crystal	Y1
Fixed inductor, 8.2µh	HL1,2,3
Screw 4-40 X 1/4 Pan Head	Mount VR1,VR2 and J14
Internal Tooth Lock Washer #4	"
Hex Nut 4-40	"
Conformal Coating	A/R
Serial Number Label	
SM24004 Manual REV. A	

DRAWING APPENDIX

GDI

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