HAMTRONICS® MO-202 DATA MODULATOR

FUNCTIONAL DESCRIPTION.

The MO-202 is designed to provide interface between computer equipment and a vhf or uhf fm transmitter module to allow digital transmisslons with audio frequency shift keying at speeds up to 1200 baud, using mark and space tones of 2200 and 1200 Hz. The unit is ideal for use with packet radio TNC's which have no internal modem, and it is also suitable for many other amateur and comrnercial applications, such as telemetry, wireless alarm systems, and teletype. In addition to tone generation, the MO-202 also supplies power to the transmitter (exciter) when the computer requests transmission, and it provides a handshake to the computer after a short pause to allow the transmitter and receiver to respond to the request. A special tone equalization network optimizes the levels of the mark and space tones for maximum transmission range, thereby counteracting circuits in the transmitter which pre—emphasize high frequency audio for voice operation.

CONSTRUCTION.

Assembly of the module is straight forward, using the diagrams and parts list. Following are some items which should receive special attention.

a. Observe polarity of electrolytic capacitors, diodes, ic's, and sockets.

b. The LED's have a longer lead for the anode (positive side). Align them for polarity as shown in the diagram.

c. The power transistor, Q5, has a metal tab, which must be aligned as shown in the diagram.

d. Install the small transistors as shown in the diagram.

e. Resistors and diodes mounted standing up are shown on the diagram with a circle indicating the position of the body and a line indicating the top lead going over to the other hole.

f. Terminal pins are supplied on a strip. Cut each one off the flashing metal, and install it in the board by pushing the pointed end through the board until the first set of dimples pops through the board to lock it in place. Be careful not to crush the barrel. The open end of the terminal will be up when properly installed. You can grip one wall of the open end with needle-nose pliers to press the terminal into the hole in the board.

THEORY OF OPERATION.

The heart of the unit is U1, which generates either of two sine-wave audio tones, depending on the level of input at pin 9. The frequency of oscillation is set by C3 in conjunction with R5-R8. When the input at pin 9 is high, the frequency of the tone is 2200 Hz (mark). When the input at pin 9 is low, the frequency is 1200 Hz (space). Led DS1 illuminates on space input as a troubleshooting aid. The oscillation can be observed with a frequency counter at pin 11 (TP-1), which has a square wave shape. Further processing in the ic results in a sine wave at pin 2. That output is low-pass filtered by R2/C1 to compensate for the EIA pre-emphasis curve of the transmitter. Normally, pre-emphasis is desirable to enhance voice communications. However, on data transmissions, pre-emphasis actually decreases the range of transmission. In order to have two equal tones on the air, R2/C1 undoes the pre-emphasis.

Various dc switching circuits are used to provide the proper levels for input and output computer signals and to key the transmitter. When used with TTL interface, the data input at E2 is applied directly to pin 9 of the ic. When an RS-232 input is used, the data signal is connected via E1, and it is inverted by Q1. When the signal is positive, Q1 conducts. When it is negative, CR1 clamps the input, and Q1 is off. Q2 operates in a similar manner for the Request to Send (RTS) input in the RS-232 case. When a TTL RTS input is applied (at E6), a lo causes Q5 to turn on via Q3 and Q4. Q5 switches B+ to the transmitter at a level up to 600 mA to key it when the computer gives an RTS command. LED DS2 indicates when the transmitter is keyed. In order to tell the computer when the transmitter is ready to accept data, allowing for time for the carrier to come up and get on frequency and time for the receiver to respond at the other end of the circuit, the MO-202 provides a CTS (clear to send) handshake after about 25 milliseconds. The delay is set by the charging time of C6 via R17. Other time delays can be set by changing the time constant of the R/C network; however, the preset 25 mSec period was chosen because Hamtronics® crystal controlled modules take about 15 mSec for complete changeover and stabilization. If you are using other equipment, especially a synthesized transmitter or one with relays, it could take considerably longer, and the R/C network would have to be changed accordingly. More on this later. The CTS output is provided to the computer in TTL form by Q6. If RS-232 form is needed, Q7 provides an additional inverting switch and provides +12Vdc switching to the computer.

TABLE 1. DC SIGNALING LEVELS.

COMMAND	DATA/TONE	TTL	RS-232
OFF	MARK 2200Hz	HI	-12V
ON	SPACE 1200Hz	LO	+12V

TABLE 2. RS-232 25-PIN CONNECTOR REFERENCE.

Function	Computer Terminal	To/ From	Module*/ Pin
Protective gnd	1	<	MO-202/E4
Transmit data	2	>	MO-202/E1
Receive data	3	<	DE-202/E1
Req to send	4	>	MO-202/E5
Clear to send	5	<	MO-202/E8
Signal grounds	7	< >	MO-202/E4, DE-202/E6
Rcv carrier detect	8	<	DE-202/E3

*DE-202 is the companion Data Demodulator.

MOUNTING THE MODULE.

Once construction is complete and the board is checked for wiring errors and bad solder joints, the module may be mounted to the chassis. The preferrable location is close to the exciter to provide short hook-up wire connections to the transmitter. The module may be mounted to chassis standoffs with 4-40 screws in the four 1/8-inch mounting holes. Although the length of leads to the computer and power supply are not critical, it is good practice to keep the audio lead to the mic input on the exciter relatively short; so a good location for the module is next to the exciter board. In selecting a mounting location and perhaps a chassis, keep in mind that you will want to have access to the mark arid space frequency adjust pots; so you want to leave extra room inside the chassis at the right side of the module.

POWER CONNECTIONS.

Power Connections depend on whether the unit will be used with TTL or RS-232 interface. For TTL computer interface, only a positive supply voltage and ground must be connected. For RS-232, it will also be necessary to have a negative supply to the board unless the computer equipment is modified.

Connect the power supply return (common) lead to MO-202 E4 (unless you can rely on a chassis ground connection through the mounting hardware and have the chassis connected to the power supply return line). The positive supply lead should be connected to MO-202 terminal E10. This should be +13.6Vdc with sufficient current capability to operate the transmitter (exciter) in addition to the circuitry on the MO-202. This normally means a current of about 600 mA max. for the transmitter and another 80 mA maximum for the circuitry on the MO-202, or about 700 mA total. The MO-202 works perfectly well on supply voltages from +10V to +15V, but the transmitter operates at full power only if the MO-202 is powered from +13.6Vdc.

If the computer interface is to be RS-232 type, then a negative 12V supply needs to be connected to E9. This is because RS-232 interconnections use ±12V (by spec., ±3Vdc or higher) instead of just switching a positive voltage on and off. The symmetrical voltage swing above and below ground is said to provide less trouble with ground return noise when two units are linked by more than a few feet; so that is why computers are linked this way. This, of course, requires a more complicated power supply arrangement than normally is used for radio equipment. One way around this extra power supply problem for most hams is to put the negative power pull-down resistor in the computer equipment instead, since the computer already has a -12V supply if it is set up for RS-232 interface. If you elect to do this, remove R23 from the MO-202 and wire it in the computer equipment (TNC) from the CTS line to the -12V power bus. It will perform the same function; just the location will be different.

TRANSMITTER B+ CONNECTION.

The transmitter is keyed at appropriate times by the MO-202, with PNP power transistor Q5 in series with the B+ to the exciter. E11 on the MO-202 should be connected to the B+ input of the exciter (usually E1 on Hamtronics exciters). If a power amplifier is used, it will operate in class C; so it will be inactive unless rf drive is applied from the exciter. Therefore, the pa should have power applied all the time; the MO-202 cannot provide enough current for the pa, too. E11 on the MO-202 can supply up to 600 mA for the exciter. It could also provide power to a small coax relay for the pa, but the total current drain on E11 must not exceed 600 mA, and you must be careful to connect a reverse diode across the relay coil to prevent inductive surges on the B+ line.

Normally, crystal controlled exciters should be used because synthesized exciters generally take much longer to stabilize on frequency when switched from receive to transmit. The Hamtronics crystal controlled exciters come up to power and frequency usually within one or two milliseconds, and additional time is needed for the receiver to recognize that a tone signal is being received. It is especially important to have a fast switching time for packet radio; since the transmissions are of short length, and you don't want the transmitter stabilization period to be sizeable compared to the transmission length, which often is much less than a second. R17/C6 in the CTS circuitry must be changed to a longer time constant if a transmitter with a long key-up time is employed. The 25mSec delay period designed into the unit should be sufficient for most crystal-controlled exciters.

TRANSMITTER AUDIO CONNECTION.

E3 on the MO-202 should be connected to the transmitter audio input (usually terminal E2 on Hamtronics exciters). The output network on the MO-202 is set up for Hamtronics exciters, and it is designed to work into a microphone input impedance of about 2000Ω. R2/CI provides a low pass filter to roughly be the reciprocal of the EIA preemphasis curve in the transmitter so that both tones are transmitted at about the same frequency deviation. The output level is set up for about 16mV p-p with the mark (2200 Hz) tone and about 22mV p-p with the space (1200Hz) tone. This matches the microphone line sensitivity of the Hamtronics exciters.

If you are using another type of exciter, it may be necessary to change the values of R2/C1 to match the needs of your transmitter. Normally, the mic gain control on the transmitter is adjusted for setting the exact deviation for the transmitter, but it is necessary to be in the right ballpark to start. R1 raises the 2000Ω input impedance of the Hamtronics exciters to about 7000Ω so that C1 is not loaded down too much to be of use in the frequency compensation scheme. As a guide, pin 2 of U1 puts out about 1.5Vp-p on either tone. The R/C network between pin 2 and the exciter must provide the proper relative and absolute levels for the two tones to match the exciter.

The connection to the exciter microphone input normally is made with hookup wire, and shielded cable is not required unless the line length will be several feet or there is ac current in nearby lines. With the MO-202 installed adjacent to the exciter board as recommended, no special procedures are necessary for the audio line connection.

DATA AND CONTROL CONNECTIONS.

Data and control signals are connected to the computer usually through a 25-pin connector according to Table 2 for RS-232 interface. If TTL interface is used, then the connections would be made to different terminals on the MO-202: E2, E6, and E7. Table 1 gives the relative signal levels for either type of interface. It is helpful to refer to Table 1; since the levels for mark/space and on/off can be confusing, especially if you try to relate them to 0's and l's. It is best to forget 0's and l's, and just refer to the table and to the relative pulse indicators on the schematic. Those indicators show the positive or negative going nature of the signals at each point in the circuit with regard to the active state, which is defined as the circuit turned on, in the case of control signals, and with regard to "space", which is the active state in the data line. (Remember that the data rests normally at "mark" when no data is being sent.) Don't forget to connect a ground line from E4 on the board to the signal ground in the computer equipment; otherwise, there may be noise on the lines or the reference may be floating.

The CTS (clear to send) output line may not be necessary in some systems. Its function is to prevent the computer from sending data until the transmitter has had sufficient time to respond to the RTS (request to send) command and the receiver has had time to respond as well. This function can also be handled in software at the computer by merely programming it not to start the data stream until a certain length of time after it sends an RTS command.

The TTL inputs on the MO-202 require current sinking of about 2 mA for the RTS line and about 20 mA for the DATA line. The current requirement for the DATA line can be reduced if desired by eliminating DS1. The TTL CTS output line can sink at least 10mA. The RS-232 input lines have a 6.8K input resistance, and the RS-232 CTS output can drive the 3000-7000Ω load specified for RS-232 standard interface lines.

INITIAL TESTING AND ADJUSTMENTS.

The easiest way to test the unit is to connect it to the transmitter but not the computer. Power should be applied, and jumper test leads can be used to exercise the board. Ground test leads can be connected to the TTL inputs as desired: DATA at E2 to cause a change from “mark” to “space” and RTS at E6 to cause the transmitter to key up.

The first test should be to verify that the transmitter does, indeed, key up when the RTS line is grounded at E6. Also, check that a CTS signal appears at the appropriate CTS output terminals when the transmitter is keyed. It should not be necessary to check the time delay; you can assume that it is correct. If you wish to check it, however, you may do so with a dual trace scope triggered on the RTS signal and comparing the CTS pulse on the scope.

To check and adjust the tone generator circuitry, connect a frequency counter through a high-impedance 10:1 scope probe (to reduce noise interference on the counter) to test point 1, which is the top lead of resistor R10 at the left side of the board. The signal at this point is a square wave, which triggers the counter nicely. First, adjust R6 for a reading of 2200 Hz within a few Hz. Then, ground the DATA line at E2, and adjust R8 for a reading of 1200 Hz.

If you wish, the output voltage of the generator may be checked with a scope. The level at pin 2 of the ic should be about 1.5Vp-p with either tone. If you have the unit connected to a Hamtronics transmitter or another transmitter with an input impedance of about 2000Ω, you should measure about 16mVp-p at the input of the transmitter with the “mark” tone and about 22mVp-p with the “space” tone.

The following procedure is recommended for setting the fm deviation on the transmitter. To do it properly, a service monitor or some other form of deviation meter is necessary. However, hams are quile resourceful in thinking up other ways to check deviation. Keep in mind that the service monitor or deviation meter does not have to be at your location. Anyone with such an instrument can monitor your signal on the air and tell you the results as you make progressive adjustments.

If you are using a dedicated transmitter for data transmission, the deviation limiter control, if any, should be set fully open. It is preferred to have two equal tones, in terms of fm deviation, without having to use the limiter, if at all possible. This minimizes any distortion in the tones and provides the greatest range of transmission without errors. In such a case, merely set the deviation with the “mark” signal, and then check it with the “space” signal to see that the deviation is about equal. Use the microphone gain control to set the deviation level.

If the two tones are not nearly equal in deviation, the easiest step to take is to increase the microphone gain control and decrease the limiter (deviation) control to cause the limiter to equalize the two tones. The better, but more difficult, procedure would be to change the low-pass network in the MO-202 (R2/C1) to more nearly compensate for the curve in your particular transmitter. It is desireable to have the two tones within about 1/2 kHz deviation of each other.

It has been found through research that the ideal deviation level for nbfm is 3 to 4 kHz, not 5 kHz. This allows for minimum distortion in the receiver on weak signals and allows for a small amount of carrier frequency error. Using an R100 Receiver for experiments, we found that the optimum 3 to 4 kHz deviation sensitivity for no error copy was 0.2μV, whereas increasing the deviation to 5 kHz required an input signal of 0.3μV to provide copy of the same quality.

If the two tones are at about the same level, but the microphone gain control just doesn’t have quite enough range to adjust to the proper level, the value of R2 on the MO-202 board can be changed slightly without affecting the compensation curve significantly.

TROUBLESHOOTING.

Finding problems should be relatively easy, since the only circuits other than an audio generator are simple dc switches. The testing procedure at the left states how to check the audio levels. Following is a voltage chart indicating de voltages at various points and under various conditions. The tests were done with +13.6Vdc power supply, because +13.6Vdc is ideal for operating the transmitter, If you have a 12Vdc supply instead, then the voltages mostly will be lower. Most problems are due to construction errors; so be sure to check all parts and connections if you have any problem. Seldom is the problem due to a bad part.

The led’s can be helpful in checking for major functions. DS1 is lit on “space” and off in “mark” data condition. DS2 is lit when the transmitter is keyed.

Current drain of the module is 80 mA max plus whatever current the transmitter draws through the module.

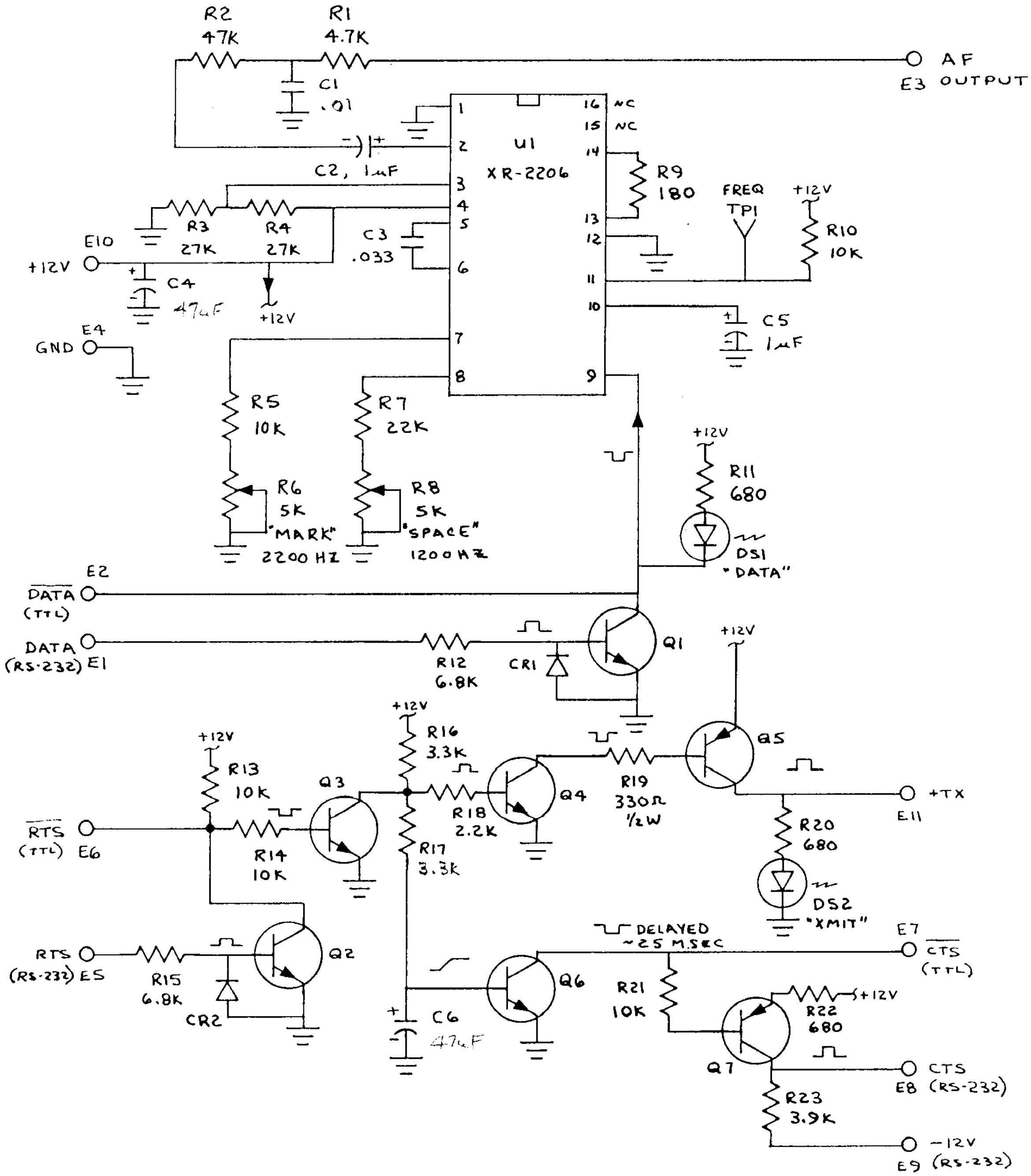
TABLE 4. PARTS LIST.

Ref Desig	Value
C1	.01µf disc (marked 103)
C2	1µf electrolytic
C3	.033µf mylar (333)
C4	47µf electrolytic
C5	1µf electrolytic
C6	47µf electrolytic
CR1, CR2	1N4148
DS1, DS2	Mini red LED
E1-E11	Solder Terminal
Q1-Q4, Q6	2N3904
Q5	TIP-30 1A pnp
Q7	2N3906
R1	4.7K
R2	47K
R3-R4	27K
R5	10K
R6	5K, 20-turn pot.
R7	22K
R8	5K, 20-turn pot.
R9	180Ω
R10	10K
R11	680Ω
R12	6.8K
R13,R14	10K
R15	6.8K
R16-R17	3.3K
R18	2.2K
R19	330Ω, ½w
R20	680Ω
R21	10K
R22	680Ω
R23	3.9K
U1	XR-2206 Function Generator IC

Table 3. DC Test Voltages with 13.6VDC Power.

U1 PIN	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
MARK	0	6.5	6.4	13.6	5.2	5.2	3.0	3.7
SPACE	0	6.5	6.4	13.6	5.2	5.2	3.7	3.0
U1 cont	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
MARK	12.3	3.0	6.8	0	3.2	3.2	1.0	1.0
SPACE	2.6	3.0	6.8	0	3.2	3.2	1.0	1.0
Q1	**E**	**B**	**C**					
MARK	0	-0.9	12.3					
SPACE	0	+0.9	2.6					
Other Xstrs	**Q2-B**	**Q2-C**	**Q3-B**	**Q3-C**	**Q4-B**	**Q4-C**		
Xmtr Keyed	+0.9	.03	.03	6.0	0.9	0.3		
Unkeyed	-0.9	7.5	0.8	.05	.05	13.0		
Other Xstrs	**Q5-E**	**Q5-B**	**Q5-C**	**Q6-B**	**Q6-C**	**Q7-E**	**Q7-B**	**Q7-C**
Xmtr Keyed	13.6	12.8	13.4	0.75	.07	13.6*	12.8*	+13.6*
Unkeyed	13.6	13.1	0	.05	12.9	13.6	12.9	-13.6*

* No load voltage; can be much less, depending on load resistance presented by computer interface unit.



Note: Some led's have a flat on one side, others have longer positive lead than negative.