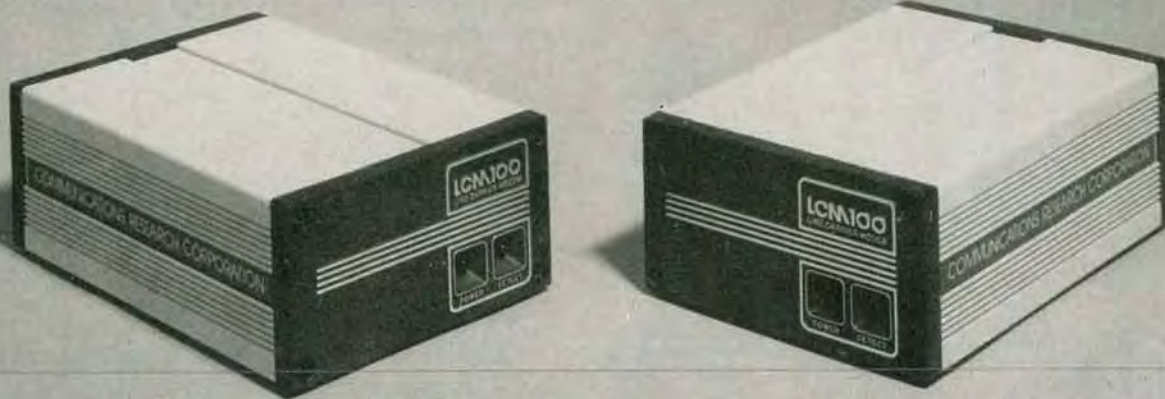


BUILD A PAIR OF



LINE-CARRIER MODEMS

*Build a pair of modems that communicate over the AC lines—
for less than \$100!*

KEITH NICHOLS, CRC ELECTRONICS

Last month when we left off, we were just about finished with our circuit description. We'll continue with a brief look at the power supply circuit, and then move on to discuss the construction details.

Power supply

The LCM100's power supply, shown in Fig. 7, consists of power-transformer T2, bridge-rectifier BR1, precision-voltage-regulators IC4 and IC5, and other associated filter capacitors. Regulators IC4 and IC5 produce the ± 12 -volt supplies required by the various IC's. In addition, fuse F1 and MOV1, a 150-volt varistor, provide protection from short circuits and voltage surges.

Construction

The line-carrier modem system is built on two identical PC boards, one of which is designated as the LCM100-01 module and the other, the LCM100-02 module. Each circuit board contains a power-supply, a transmitter, a receiver, an output driver, an RS-232C interface, and carrier-detect circuitry. All components on the two boards except C3, C26, C29, C32, C36, R10, R27, R33, and R34 are identical.

Begin assembly by installing the resistors, including the variable potentiometers. Use the parts-placement diagram shown in Fig. 8. Keep in mind that R10, R27, R33, and R34 have different values on the two boards. Note that R9 is not used.

Next, install all jumper headers, test pins, J1, J2, and the fuse clips. Note that the fuse clips must be oriented with the indented ends away from the fuse. Connectors J1 and J2 should be secured to the board with 4-40 hardware before soldering.

The capacitors and diodes are installed next, except the electrolytic capacitors, C6 and C11. Be sure to observe the polarity of the diodes and the tantalum capacitors, C12 and C17. Again, note that capacitors C3, C26, C29, C32, and C36 have different values on the two boards.

Next, install IC1, IC2, IC3, IC6, and IC7. The use of IC sockets is recommended to minimize the possibility of damage to the IC's from excess heat. However, if you choose not to use sockets, insert the IC's carefully and solder only a few legs at a time to keep heat to a minimum. Note that pin 1 on all IC's point toward the same side of the PC board.

Transistors Q1, Q2, and Q3, varistor MOV1, and IC4 and

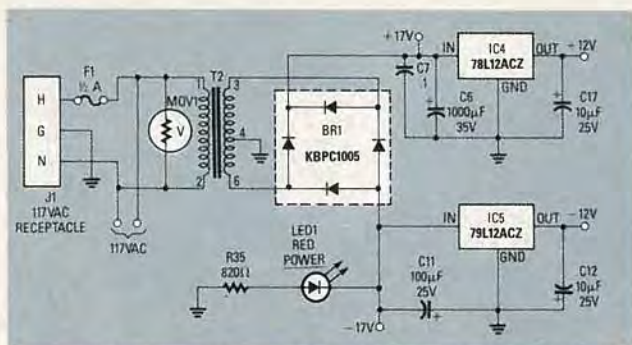


FIG. 7—THE LCM100's POWER SUPPLY. Regulators IC4 and IC5 are precision types; don't interchange them!

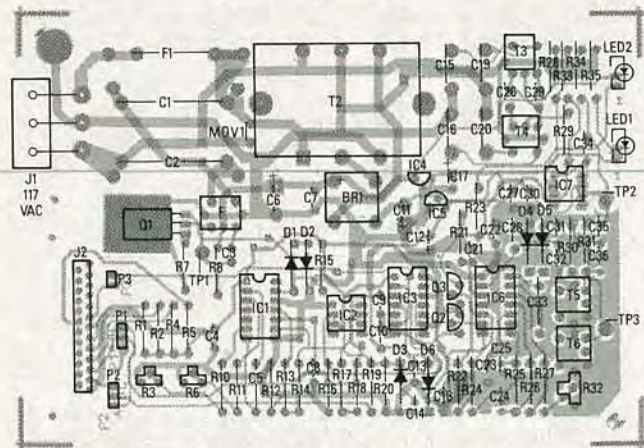


FIG. 8—INSTALL ALL COMPONENTS as shown here.

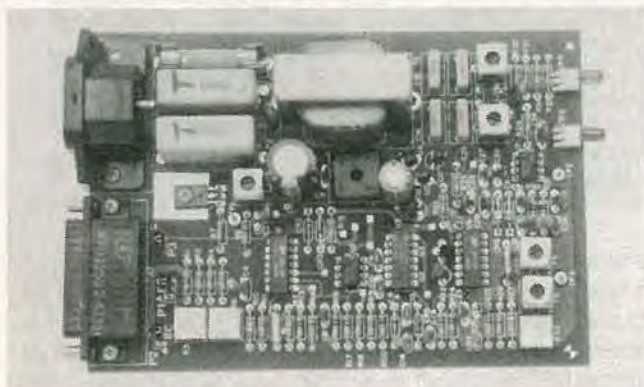


FIG. 9—THE FINAL ASSEMBLY looks like this.

IC5 are installed next. Use care not to interchange IC4 (78L12A) and IC5 (79L12A), the +12- and -12-volt regulators. Note that transistor Q1 should be secured to the PC board with a 4-40 screw and nut prior to soldering. Use extreme care not to overheat the transistors and IC's when soldering. It's a good idea to attach heat-sink clips to the individual component legs when soldering to minimize heat flow to the component.

The tunable RF coils are installed next. Note that T1 (TOKO RAN 10A6729HK) has a different part number than T3, T4, T5, and T6 (TOKO RAN 10A6729). When installing the RF coils, be sure to solder all 5 pins plus the two housing tabs to the PC board.

Next, install the power transformer (T2), bridge-rectifier BR1, electrolytic capacitors C6 and C11, and the LED's. Be sure that the correct polarity is observed when installing the electrolytic capacitors and LED's. The cathode (or flat

side) of the LED's goes toward the center of the PC board. Transformer T2 must be installed with leads 1 and 2 (120 V) toward the AC receptacle (J1). Bend the mounting tabs against the board and solder them, as well as the six transformer leads, to the board. Also, be sure that bridge-rectifier BR1 is installed with the (+) lead closest to pin 2 of T2.

Last, if you used sockets for the IC's, carefully insert the IC's in their respective sockets. Be sure orientation is correct before inserting the IC's. Figure 9 shows the final assembly.

Testing and tuning

1) Begin testing by thoroughly inspecting both boards for missed or inadequate solder joints, solder bridges, etc. Because double-sided PC boards with plated-through holes are used, solder will normally flow through the holes to both sides of the board. However, if you have chosen to make your own PC boards (the patterns are shown in PC Service), be sure to solder the component leads on both sides of the board where appropriate!

Caution! Working directly with AC power is dangerous, so be careful! Before applying power to the circuit, be sure to place the board on a non-conductive surface, and do not touch any exposed leads or traces on the line-voltage side of the circuit!

2) With the assembled board on a non-conductive surface, install F1 (½ amp) in the fuse clips, then connect a three-wire power cord to receptacle J1 and apply power to the circuit. **Keep your hands away from the high-voltage components and traces on the board!** The red LED (D9) should light, indicating that power is on. The green LED may flicker momentarily; however, it should not remain lit.

3) Now connect a temporary switched jumper between the data-input pin of J2 (the DB25P connector) and one of the +12-volt sources (pin 4, 5, 6, or 20 of J2). A convenient way to do that is to use a spare DB25P male connector with an SPST switch wired across the pins to be jumpered. You might want to make a separate jumper for each board, because the data input is pin 3 on the LCM100-01 board and pin 2 on the LCM100-02 board. If you haven't already done it, install the jumpers on headers P1, P2, and P3 as follows. On the LCM100-01 board: P1, P2—A and B jumpered; P3—not jumpered. On the LCM100-02 board: P1, P2—B and C jumpered; P3—jumpered.

4) The next step is to adjust the mark and space frequencies of modulator IC1. Begin with the LCM100-01 board. Attach the input lead of a frequency counter to TP1 (the collector of Q1), and the ground lead to pin 1 or pin 7 of the DB25P jumper. With the jumper switch on, adjust R3 until the meter reads 150 kHz. That is the "space" frequency (f1) of the FSK modulator. Next, turn the jumper switch off and adjust R6 to get a reading of 156.5 kHz. That represents the "mark" frequency (f2). Switch between f1 and f2 several times while fine tuning R3 and R6 until both frequencies are correct.

5) The transmitter line coupler can now be tuned to the modulator's FSK band as follows: Attach a high-impedance oscilloscope probe (×10 setting) to TP1, and clip the ground lead to pin 1 or pin 7 of J2. Set the sweep time

PARTS LIST

Note: Component values in parentheses are for the LCM100-02 board; other values are for the LCM100-01 board.

All resistors are 1/4-watt, 5% unless otherwise noted.

R1, R2, R4, R5, R15, R19, R28, R29—4700 ohms
 R3—5000 ohms, PC-mount trimmer potentiometer
 R6—200,000 ohms, PC-mount trimmer potentiometer
 R7—4.2 ohms
 R8—300 ohms
 R9—not used
 R10—17,400 ohms, 1% (24,900 ohms, 1%)
 R11—360,000 ohms
 R12—3900 ohms
 R13—5100 ohms
 R14—3000 ohms
 R16, R20, R22, R30, R31—10,000 ohms
 R17—150,000 ohms
 R18—220,000 ohms
 R21—470,000 ohms
 R23, R35—820 ohms
 R24—510,000 ohms
 R25—100,000 ohms
 R26—300,000 ohms
 R27—24,900 ohms, 1% (16,200 ohms, 1%)
 R32—5000 ohms, PC-mount trimmer potentiometer
 R33, R34—100,000 ohms (47,000 ohms)

Capacitors

C1, C2—1 μ F, 135 volts
 C3—1800 pF (3900 pF)
 C5—330 pF
 C6—1000 μ F, 35 volts, electrolytic
 C4, C7—C10, C13, C18, C22, C23, C27, C30—0.1 μ F, 25 volts, monolithic
 C11—100 μ F, 25 volts, electrolytic
 C12, C17—10 μ F, 25 volts, tantalum
 C14, C25, C33—330 pF
 C15, C16, C19, C20—0.1 μ F, 135 volts
 C21—3900 pF
 C24—100 pF

C26, C29, C32, C36—3900 pF (1800 pF)
 C28—0.01 μ F, disk
 C31, C35—470 pF
 C34—6.8 pF

Semiconductors

BR1—50 volts, 1 amp
 D1, D2, D3, D6—1N4148
 D4, D5—1N4728 (3.3-volt Zener)
 LED1—standard red
 LED2—standard green
 IC1—XR2207, FSK modulator
 IC2—LM311N, op-amp
 IC3—1488, RS-232 line driver
 IC4—78L12ACZ, precision +12-volt regulator
 IC5—79L12ACZ, precision -12-volt regulator
 IC6—XR2211, FSK demodulator
 IC7—LM318N, op-amp
 Q1—MJE180, NPN power transistor
 Q2—PN2222, NPN switching transistor
 Q3—2N3906, PNP switching transistor

Other components

J1—115-volt AC receptacle J2—25-pin D connector P1, P2—3-pin header strip P3—2-pin header strip MOV1—150-volt varistor T1—RF coil, TOKO RAN10A6729HK T2—24-volts, 180 mA, PC mount (Dale PL-13-07) T3—T6—RF coil, TOKO RAN10A6729

Miscellaneous

Note: The following are available from CRC Electronics, 13547 S. E. 27th Place, Suite 3D, Bellevue, WA 98005, (206) 747-9636: Etched and drilled PC boards with plated-through holes, \$24.95/pair; Partial kit (includes PC boards, all transformers, coils, jacks, and high-voltage capacitors) \$49.95/pair; Complete kit excluding case and power cords, \$99.00/pair; Assembled and tested PC-board assembly without cases and power cords, \$119.95/pair; Complete assembled and tested system, \$159.95/pair. Individual components are also available.

and amplitude controls to display a sine wave. Adjust the tuning slug of RF-transformer T1 until maximum amplitude is obtained. Now flip the DB25P jumper switch to the other position and observe the change in amplitude as the frequency changes. Adjust T1's tuning slug until the amplitudes of f_1 and f_2 are equal. Repeat steps 2 through 5 with the LCM100-02 board, using 100 kHz and 106.5 kHz as the f_1 and f_2 settings respectively.

6) The receiver-stage line couplers are similar to the one used in the transmitter except that two of them are configured in a parallel arrangement. That permits precise tuning to the mark and space frequencies individually, rather than using an average of the two. The result is greater receiver sensitivity and superior noise rejection.

Tune the receiver line couplers as follows: Attach a scope probe ($\times 10$ setting) to TP2 (pin 6 of IC7) on the LCM100-01 board. Be sure to clip the ground lead to the signal ground, as before. Connect the power cords to both boards and plug both cords into the same 115-volt outlet box. The volts/division setting of the scope should be increased a couple of notches from where it was set for TP1. Adjust the tuning slug of T3 or T4 until an increase in amplitude of the waveform is seen on the display. Continue adjusting the slug until maximum amplitude is

obtained. You may need to adjust both T3 and T4 in order to do that. When the amplitude exceeds a certain point you will see the peaks of the sine wave flatten out as the Zener diodes (D6 and D7) chop the voltage at ± 3.3 volts. Flip the DB25P jumper switch on the LCM100-02 board to shift the frequency, then readjust T3 or T4 (on the LCM100-01 board) until the maximum amplitude is seen on the scope. Now, toggle the LCM100-01 jumper switch several times while fine tuning T3 and T4 until both f_1 and f_2 frequencies appear to have equal amplitude on the scope display. The waveform should look like a symmetrical sine wave with flattened peaks. Repeat step 6 for the LCM100-02 board (using the DB25P jumper switch on the LCM100-01 board to shift the frequencies).

7) The next step is to align the bandpass-filter network. The procedure is the same for each board. Attach the scope probe ($\times 10$ setting) to TP3 (the ungrounded end of T6). Adjust the tuning slug of T6 until maximum amplitude of the sine wave is displayed. Toggle the jumper switch (on the opposite board) and fine tune T6 until an equal amplitude is obtained for both frequencies. Next, adjust T5 in the same manner as T6; note that T5 affects the amplitude very little.

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8) The final tuning step is to adjust the free-running frequency of the VCO in the XR2211. The simplest way to do that is to adjust R32 while observing the green LED (D8) on the board (the opposite board, of course, must be plugged in and transmitting). Turn the adjustment screw of R32 until the green LED lights, then continue turning in the same direction until it turns off again. Set the adjustment screw of R32 halfway between the two points and mark the position of the screw slot with a pencil. Now flip the jumper switch on the opposite board to change the frequency, and repeat the previous step. You should have two pencil marks on R32 a few degrees apart. Turning the adjustment screw halfway between the two marks should result in the correct setting. Repeat that step for the other board.

8-a) A more accurate method of setting the VCO of the XR2211 is as follows: Configure a function generator to produce a 4800-Hz square wave with a voltage swing of zero to +6 volts. Use that signal to adjust your oscilloscope to display a symmetrical square wave. Next, attach the function-generator output lead to the DATA-IN pin of J2 on the LCM100-01 board. Make sure the jumper switch is in the off position. Attach the scope probe to the DATA-OUT pin of J2 on the LCM100-02 board. With the power on to both boards, adjust R32 (on the LCM100-02) until a symmetrical square wave is displayed. That indicates the correct setting of the oscillator at the "center frequency," the midpoint between the detector mark and

space frequencies. The green LED will, of course, be on at that setting.

Repeat the previous step, reversing the two boards, to complete the "tuning" process. The final step is to test the modems by transmitting actual data.

9) To do so, you'll need a serial-data output source. A video terminal, in full-duplex configuration, will do nicely. A simple loop-back circuit is the easiest test. The terminal is connected to the LCM100-01 modem that is plugged into the power line. The LCM100-02 modem, with pins 2 and 3 of J2 jumpered together, is plugged in some distance away. As you type on the keyboard, the data is transmitted to the LCM100-02 modem, looped back through the jumper, and re-transmitted to the LCM100-01 modem where it appears on the terminal's screen. Depending on your terminal's configuration (DTE/DCE), you may need to transpose the two modems or switch the internal jumpers on the LCM100-01 modem board to get things working properly.

The LCM100 will successfully transmit data over distances of several hundred feet, or more, at rates up to 9600 bps. In general, the greater the distance, the lower the baud rate should be for error-free transmission. It is best to experiment with different transmission rates and distances to establish reliable operating parameters for your AC line.

The ultimate range is limited by the power company's step-down transformer and the cross-coupling between the 115 V legs of a 230-volt distribution system. You can arrange communication between the latter by attaching a fused capacitor (a 1- μ F, 400-volt capacitor in series with a 1/2-amp fuse) between the two 115-volt legs in your electrical panel box. 