INOVONICS
I N C O R P O R A T E D

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**OPERATING AND MAINTENANCE
INSTRUCTION MANUAL**

MODEL "PBX"

TELEPHONE SWITCH

———

INOVONICS
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Section I

INTRODUCTION

Product Description

Inovonics' "PBX" is a telephone switching "mini-system." It allows up to seven dial-up devices (modems, fax machines, alarm boxes, telephone sets, etc.) to share a single central office telephone line, both for outgoing and for incoming calls. The PBX delivers central office dial tone to the first modem or other device which goes off-hook to originate a call. Calls incoming to the PBX are directed to the selected device with a touch-tone® access command from the calling party.

Product Features

Features of the Inovonics PBX include:
- Easy installation with standard RJ11 jacks for telco line and subscriber equipment.
- Two or more PBX units may be daisy-chained to accommodate additional dial-up devices.
- 90-volt / 20Hz ringing voltage generated internally.
- Powered by mains-voltage adapter (supplied), or by Uninterruptible Power Supply (UPS) at user's option.

Product Applications

The PBX finds primary utility in remote, unattended equipment installations which may be limited to a single central office phone line. Such installations might include broadcast transmitter sites, emergency power plants, pumping stations, radio repeater huts and weather monitoring locations. In short, any installation of electronic equipment for monitoring, alarm or dial-up interrogation which requires occasional, intermittent access to a standard telephone line.

Product Specifications

Central Office Compatibility: Standard 48-volt, 40mA subscriber loop equipped for touch-tone service. Connection via RJ11 jack, polarity protection provided.

Subscriber Set Compatibility: Accepts any modem, tel-set, fax machine, alarm equipment, etc. intended for direct connection with a touch-tone-equipped central office telephone line. Connections via RJ11 jacks.

Panel Indicators: POWER, C.O. CONNECT, MODEM CONNECT on front panel. Rear-panel indicators next to each jack light when that device goes off-hook.

Power Requirement: 12VAC at 500mA. A "wall-transformer" power supply is provided. The PBX will also operate from an external DC source between 15V and 20V.

Size and Weight: 2"H x 6"W x 8"D; 4 lbs. (shipping).

Section II

PBX INSTALLATION

Unpacking and Inspection

Inspect for possible shipping damage immediately upon receipt of the equipment. If damage is suspected, notify the carrier at once, then contact Inovonics.

We recommend that you set-aside the original shipping carton and packing materials for possible reuse. In the event of return for Warranty repair, shipping damage sustained as a result of improper packing *may invalidate the Warranty!*

> **IT IS VERY IMPORTANT** that you complete and return the Warranty Registration Card found at the front of this Manual. Not only does this assure coverage of the equipment under terms of the Warranty, and provide some means of trace in the case of lost or stolen gear, but the user will automatically receive specific SERVICE OR MODIFICATION INSTRUCTIONS should they be issued by Inovonics.

Mounting

The Inovonics PBX is packaged in a plastic box with rubber feet. Though no provision is included for rack-mounting, the unit may be set atop any convenient rack-mounted chassis, so long as at least 2U of panel space *above* the "host" equipment is left open to access the PBX. Alternatively, the PBX may be located next to the telephone company's "demarc" and fastened to the wall or mounting board with a couple of small angle brackets from the hardware store. Short sheet-metal screws will secure the brackets to the plastic enclosure.

AC Mains Power

The PBX is supplied with a 115-volt, "wall-mounted transformer" power supply. The actual power delivered to the PBX is 12 volts AC at about 500mA. Though the input power to the PBX is thus defined, we nonetheless recommend that you use the supplied "wall wart" whenever possible.

If the PBX is expected to function during a mains power failure, whatever standby supply is available for the other equipment can probably operate the PBX as well. If this is a 115-volt AC mains supply, no special provision is necessary. If, on the other hand, other equipment at the location draws power from a battery backup, the PBX may be powered from this as well. Appropriate DC may be fed directly in to the rear-panel connector labeled POWER (12VAC) without regard to supply polarity. This DC feed should be pre-regulated to a value between 15VDC and 20VDC. If, for example, the standby power source is a 24-volt battery supply, a simple series regulator may be arranged using a common "3-terminal" voltage regulator integrated circuit such as the *National Semiconductor* LM7815CT.

Radio Frequency Interference (RFI)

We have anticipated that the PBX may be installed in the immediate proximity of broadcast transmitters or 2-way radio equipment. Nevertheless, please practice some care in locating the unit away from *abnormally* high RF fields.

Front Panel Indicators

POWER
This LED lights only when the proper voltage is delivered to the PBX. An voltage somewhat below the required input will cause the indicator to go out, though the unit may appear to function properly.

C.O. CONNECT
This indicator lights whenever the central office (telco) line is engaged, either for calls outgoing from, or incoming to, the PBX.

MODEM CONNECT
This lights when one of the connected devices (modem, etc.) is active. For an outgoing call, this LED will light concurrently with the C.O. CONNECT indicator as the telco line is seized. When the PBX answers an incoming call, this LED will light once the desired device has been selected with the appropriate touch-tone address, rung-up and has answered.

Rear Panel Connectors and Indicators

POWER (12 VAC)
This "coaxial power" connector mates with the plug molded onto the end of the "wall wart" power supply cord. Nominal connector dimensions are 5mm O.D. by 2.5mm I.D. This is a common connector *(Radio Shack #274-1568),* should one be required for alternative power accommodations. (Note particulars at the top of the previous page.)

TEL LINE
This US-standard RJ11 jack connects the PBX to the tip and ring of the central office telephone line. Use any standard, 4-conductor "modular-to-modular" telephone set mounting cord, such as *Radio Shack #279-347* (6-foot), *#279-374* (12-foot) or *#279-356* (25-foot).

MODEMS (1 – 7)
These seven RJ11 jacks interconnect the PBX with the various pieces of equipment which will share the common central office telephone line. The same "modular-to-modular" cables may be used as listed above. *NOTE:* MODEM 7 is designated a "Priority Channel." See explanation below.

Each jack has an associated LED to indicate which piece of equipment is connected to the central office line.

Connecting the PBX

As hinted in the foregoing description of rear-panel appointments, the "wall-wart" power supply is plugged into the POWER (12 VAC) socket. The central office line is connected to the TEL LINE jack, and modems, etc. are assigned to the seven MODEM jacks. Nothing could be simpler, could it?

The use of a second PBX to accommodate additional equipment is covered on Page 8.

"Priority Channel"

The MODEM 7 jack has been designated a "priority channel." Whenever the device plugged into this jack goes off-hook: 1) any existing outgoing or incoming connection is unceremoniously "dumped," 2) the central-office line is restored to an idle condition with a two-second delay, and 3) MODEM 7 equipment is connected directly to the line.

If an incoming call is in progress when the MODEM 7 "priority" device seizes the line, the priority device may not immediately receive and recognize dial tone. Modern modems will not blindly "dial away" into a dead connection, but will hang up and try the call again. Results may well depend on the communication protocol of the equipment which originated the interrupted call. Once communication has been broken by the *called* modem being disconnected, the *originating* equipment may immediately hang up and then attempt to re-establish communication. You may wish to edit the dialing routine of such gear, adding a "wait" command to allow the priority device a chance to seize the line.

MODEM 7, the "priority channel," should be assigned to equipment with a vital or sensitive function; a fire or water-level alarm, for instance. Another candidate might be a remote control system with a paging provision which automatically summons a technician in an emergency.

Section III

PBX OPERATION

Calls Outgoing From the PBX

In the idle state of the PBX, the first modem or other equipment to go off-hook will seize the telco line and receive central office dial tone. Once this connection is made, the equipment has a direct, *"metallic"* connection with the central office line which will be maintained without interruption until the modem "hangs-up." *The PBX does <u>not</u> have a call-duration "timeout" provision.* The single exception to this rule is an off-hook by "priority channel" equipment connected to the MODEM 7 jack. Anything connected to this jack has immediate priority over any outgoing or incoming call. (See Page 5.)

Calls Incoming to the PBX

Assuming an idle state, an incoming call will be answered by the PBX on the very first ring. When the PBX goes off-hook, it does not return a "second dial tone." It will wait for a *valid* touch-tone command for only 10 seconds before hanging up and releasing the line. During this 10-second "window," the PBX will respond to the proper "security password," followed by a single-digit "device number" to ring the desired equipment.

The security password is: ✳ - **5** - **#** ("star," the number "5" and the "number symbol" or "pound sign"). This should be followed immediately by the number of the device to be rung. For instance, ✳ - **5** - **#** - **3** would ring the device connected to the MODEM 3 jack. If the PBX receives an incorrect security password, or no touch-tone command at all, it will hang up at the end of the 10 second window.

When it receives the proper "access string," the PBX applies ringing voltage to the selected device. The ringing signal conforms to the standard established in the halcyon days of the Bell System: 90 volts AC at 20Hz, one second on, two seconds off. The PBX will disconnect if the selected device does not answer within ten rings.

Formatting Auto-Dial Commands

When equipment connected to the PBX is to be called-up and interrogated automatically from a "home" location, the programmed dialing command must be formatted to insert the security password and device address.

Since the PBX has a fixed, 10-second window to receive this information, it is important to know how soon this window opens after the last digit of the telephone number is entered. Within the same exchange this could be almost instantaneous. Since nearly all telephone exchanges now utilize digital switching equipment, there is a very short connection delay even on a coast-to-coast call. Nevertheless, it is worth placing a call to the PBX from a conventional touch-tone telephone to confirm the average connection time in seconds.

Most modems which offer programmed dialing are able to insert additional access codes, area codes and pauses in the dialing process. Though these usually *precede* the telephone number to be dialed, there is no reason why they cannot be placed *after* the number. You must consult the specific instructions supplied with the auto-dialing modem, of course, but many modems accept *commas* in the dialing string to initiate one-second pauses wherever they are inserted. If the connection delay is established at one or two seconds, insert two or three commas between the telephone number and the additional digits. For instance, dialing:

$$5 - 5 - 5 - 1 - 2 - 1 - 2 - , - , - , - * - 5 - \# - 3$$

would dial the PBX, pause three seconds while the connection was completed and the PBX has answered, then forward the security password and ring device number 3.

The PBX returns "audible ringing" to the calling party as the selected device is actually rung-up. This acknowledges receipt of the proper security password and monitors progress of the connection at the remote site.

Using Two or More PBX Units

One might ventue that a half-dozen dial-up devices could tax the limit of a single telco line, even when the intermittent nature of equipment usage is taken into account. There may be instances, however, when additional equipment may safely be accommodated by using two or more PBX units.

Interconnection is simple. The TEL LINE jack of the second, "slave" unit is plugged into one of the MODEM jacks of the first, "master" PBX. You would probably *not* choose MODEM 7, unless *all* equipment accessing the "slave" PBX wants to be assigned priority over devices plugged into the "master."

Don't forget that the dialing routine for an incoming call must contain a second, identical security password and a device address to reach equipment plugged into the "slave." As an example, let's assume that the "slave" is plugged into the MODEM 2 jack of the "master" PBX. To reach "slave" device number 4, you would need to dial:

5 - 5 - 5 - 1 - 2 - 1 - 2 - , - , - , - ✳ - 5 - # - 2 - , - , - ✳ - 5 - # - 4

The Security Password

All Inovonics PBX units respond to the same security password: ✳ - 5 - # . This gives a modest level of protection from casual "hackers," though it is assumed that modems or other dial-up equipment connected to the PBX will incorporate additional security protection if it is deemed necessary.

The PBX security password cannot be changed in the field. It is resident in ROM, integral with PBX microprocessor control.

Section IV

CIRCUIT DESCRIPTIONS

Schematic Diagram Notes

This explanation of circuit operation refers to the several pages of schematics which follow this text.

Schematic component reference designations may at first appear to be annotated in a somewhat haphazard manner. Rather than annotate the *schematic* in a logical sequence, we chose instead to designate the *components on the circuit boards* following their physical placement, top-to-bottom, left-to-right. It is our expectation that this practice will prove the more useful during troubleshooting, making it easier to locate the physical part or test point from an analysis of the circuitry.

PBX circuitry is contained on two, double-sided printed circuit boards. The larger "main board" is fastened to the lower case-half of the plastic cabinet. DC power and 20Hz ringing supplies, common-control logic, central office line circuitry and components associated with MODEMS 5, 6 and 7 are located on this board. Schematic reference designations on this board begin with "1" (R1, C1, IC1, etc.).

The "auxiliary board," which plugs into the main board, contains circuitry for MODEMS 1, 2, 3 and 4. Components on this board are in the "200" series (R201, Q201, etc.).

The "PIC" Microcontroller

The PBX employs an integrated circuit called a "PIC," or Peripheral Interface Controller, IC3 on the schematic diagram. The PIC is a simple, single-chip microprocessor with on-board, factory-programmed ROM memory. Though limited in intelligence, it is ideal for the elementary logic and simple control functions required for PBX operation.

Each separate function of the PIC will be described along with the circuitry it supports.

PBX Operation for Outgoing Calls

Assuming an idle state, as MODEM 1 goes off-hook Q207 is turned on by current through R217 and the normally-closed contacts of relay K204. IC1 routes a corresponding 3-bit binary address to the PIC microcontroller, IC3.

The PIC actuates relay K204 through a binary decoder, IC2, and driver transistor Q208. It also actuates relay K5, connecting MODEM 1 to the telephone line through normally-closed contacts of relay K4. The front-panel MODEM CONNECT indicator lights when K5 is actuated.

OP1 is an optical coupler which monitors central-office loop current. About 5mA flows through the coupler, the balance is shunted by transistor Q7. When MODEM 1 finally hangs up, OP1 turns off and the PIC restores an idle state.

For the duration of the call, the PIC will ignore an off-hook from any other device, except for the device connected to the MODEM 7 jack. Should this device go off-hook during a call in progress, the PIC immediately aborts that call, restores an idle condition, then waits for 2 seconds before connecting the MODEM 7 equipment to the central-office line. MODEM 7 is a "priority channel" which will interrupt all calls, outgoing and incoming alike.

PBX Operation for Incoming Calls

Central-office ringing is detected by optical coupler OP2. C7 blocks central-office DC. The first few cycles of ringing voltage drive Q10 into saturation, this logic alerts the PIC to an inbound call. The PIC then actuates relay K4 through transistor Q8, lighting the C.O. CONNECT indicator as well. A DC path through the primary of line-coupling transformer T1 gives an off-hook to the central-office line, thus "answering" the incoming call. This initiates the 10-second "window" during which the proper security password must be received, otherwise the PIC will hang up and restore an idle state.

The secondary of T1 is coupled to IC4, a touch-tone decoder chip. Binary touch-tone logic from IC4 is routed to the PIC. The PIC looks for the valid security password followed by a single-digit device address, MODEM 1, for this example. When this information is properly decoded, the PIC actuates K204 and applies the 90-volt, 20Hz ringing voltage through normally-closed contacts of K5. The PIC is programmed to restore an idle state

if the device does not answer within 10 rings. Audible ringing is returned to the calling party with a sample of the 20Hz square-wave coupled through R## into T1.

When the device answers, DC current supplied by R33 through CR14 is sensed by the loop-current monitor, OP1. The PIC then actuates K5 and releases K4 to connect the MODEM 1 device directly to the central-office line. OP1 continues to monitor the loop current, and when the incoming call is completed the PIC restores the PBX to an idle state.

20Hz Ringing Supply

To generate the 90VAC ringing voltage, the PIC generates a complex, "composite" waveform at pin 24. This is a 10kHz squarewave "carrier" keyed on-and-off at the 20Hz ringing frequency, the 20Hz having a 1-second "on" period followed by 2 seconds "off." The composite waveform saturates Q12, driving the primary of T2. The high frequency carrier allows a relatively small transformer to step-up the 20Hz ringing voltage.

CR15 and CR16 perform a voltage-doubling "recovery" of the 20Hz component of the composite waveform. Q11 is an active part of this recovery process, being driven at the 20Hz rate by pin 23 of the PIC. C10 and C11 remove the 10kHz "carrier" frequency.

DC Power Supplies

Raw AC from the secondary of the 12VAC wall-mounting power transformer is applied to bridge rectifier CR12. This rectifier also allows the PBX to be powered from an appropriate external DC supply without regard to input polarity.

Unregulated DC from CR12 has a value of approximately +15 volts. When the PBX is powered by an external "standby" DC supply, the applied DC should be close to this value. Should raw DC fall much below 15 volts, Q13, held in saturation through 12-volt zener diode CR17, will extinguish front-panel POWER indicator I4.

IC5, along with L1 and other associated components, is a switching regulator to transform the raw +15VDC to a regulated +5VDC supply for the digital ICs and other control circuitry.

Parts Listing

Component parts used in the PBX are listed either *en-masse,* or individually by schematic component reference designation. The listing may, or may not, specify a manufacturer by name. When no manufacturer is called-out, the term "open mfgr." advises that any manufacturer's product is acceptable, as long as it carries the requisite generic part number.

If a component is not listed at all, this means that we do not consider it a typical replacement item. Should you need to identify or order an unlisted part, call, write or fax us with a brief description. We'll do our best to figure out what you need and how to get it to you.

Unless specifically noted by component reference designation below, **capacitors** are specified as follows:

a) **100pF to 0.47μF** are metalized mylar or polyester. Whole number "P" values are picofarads, decimal values are microfarads; ±5%, 50VDC or better. The style used in the 701 is the "minibox" package with a lead spacing of 0.2 inch. (Wima MKS-2 or FKC-2 series, CSF-Thompson IRD series, of Roederstein KT-1808 or KT-1871 series.)

b) **1.0μF and above** are radial-lead electrolytics, 25VDC; (open mfgr.)

C2,6,13,14	Capacitor, Monolithic Ceramic, 0.1μF, 50V; (open mfgr.)
C8	Capacitor, Electrolytic, Axial Leads, 1000μF, 35V; (open mfgr.)
C10,11	Capacitor, Electrolytic, Radial Leads, 1.0μF, 160V; (open mfgr.)
C15	Capacitor, Electrolytic, Radial Leads, 1000μF, 10V; (open mfgr.)
CR1,2,3, 5,6,8,9, 13,201, 203,204	Diode, Silicon Signal; (open mfgr.) 1N4151
CR4,14, 15,16	Diode, Silicon Rectifier; (open mfgr.) 1N4005
CR7,12	Bridge Rectifier; ##
CR10,11	Diode, Zener, 3.9V; (open mfgr.) 1N5228B
CR17	Diode, Zener, ##; (open mfgr.) 1N##
CR18	Diode, Power Schottky; (open mfgr.) 1N5820

CRES1	Ceramic Resonator, 4MHz; *##*
I1-3, 201-204	LED Indicator, diffused pastel red, T-1 package; Stanley MVR 3378S
I4	LED Indicator, diffused pastel green, T-1 package; Stanley MPG 3878S
I5,6	LED Indicator, diffused pastel yellow, T-1 package; Stanley MAY 3378S
IC1	Integrated Cct.; (open mfgr.) 74HC148
IC2	Integrated Cct.; (open mfgr.) 74HC138

IC3	Integrated Cct.; *SPECIAL FACTORY-*
	    PROGRAMMED "PIC," type 16C62A;
	    Order by designation, reference Model PBX.

IC4	Integrated Cct.; *##* CM8870PI
IC5	Integrated Cct.; National LM2575-5 (Uses Aavid 574602 B03700 Heat Fin)
J1-4, 201-204	Connector, RJ11 "Modular Telephone Jack"; Mouser *##*
J5	Connector, Power Input; Mouser 163-5004
K1-5, 201-204	Relay, DPDT, 5V Coil; Mouser *##*
L1	Inductor, Switching Supply; Renco RL1952
OP1,2	Optical Coupler; NEC 2501
Q1,3,5,7,8, 9,10,13,14, 201,203, 205,207	Transistor, NPN; (open mfgr.) 2N3904
Q2,4,6, 202,204, 206,208	Transistor, PNP; (open mfgr.) 2N3906
Q11	Transistor, NPN; (open mfgr.) MPSA42
Q12	Transistor, NPN; (open mfgr.) TIP120

All fixed resistors are ¼-watt, 5% carbon film type, value per schematic diagram.

T1	Transformer, Telephone Coupling; Mouser *##*
T2	Transformer, Miniature Audio; Mouser *##*
—	Power Transformer, wall-mounted, 12.0 VAC @ 0.5A; Jameco 101258
X1	Protector, Voltage "Crowbar"; *##*
XTAL1	Crystal, 3.579545MHz; (open mfgr.)

Mail-Order Component Suppliers

Certain mail-order electronics distributors have proven them-selves reputable suppliers of both large and small quantities of parts. Any semiconductor, IC, capacitor, resistor or connector used in the Model 701 is *probably* available from one or more of these firms. Each supplier publishes a full-line catalog available free for the asking.

Mouser Electronics — Call (800) 346-6873

Digi-Key Electronics — Call (800) 344-4539

ACTIVE (div. of Future Electronics) — Call (800) 677-8899

Schematic Diagrams

The following pages contain a complete schematic diagram of the Model PBX Telephone Switch. The original drawing has been disassembled and reduced to fit the diminutive format of this Manual. The presbyopia-challenged may obtain a full-size diagram, simply for the asking, by sending a self-addressed 9-by-12-inch envelope to Inovonics.

PHONE LINE
J4
1
2
3
4

X1

CR10
AC +
4   1
3   2
AC −

+5

K4

K5

CR17   R35
1K
+12

T2

CR19   CR18
C14   C13
1   1

R1

Q

CR11

Q8

+5

CR12

Q9

R23
1K

I6
MODEM CONNECT

R36
1K

R38
1K

I5
C.O. CON.

R22
1K

T1

R26
1K

Q11

R37
1K

R30
10K

R25
1K

CR8

CR9

R24
1K

C10
.1

CR13   CR14

C7
.1

IC4

+5

2   IN−   VDD   18
              VOE   10

R27
10K

3   GS

CR16

R28
10K

1   IN+

OP2

R31   R32   R33
10K   10K   10K

+5   +5

4   REF

GT   17

C8
.1

R29
300K

7   OSC

XTAL1

ES   16

C12
10

Q10

8   OSC

ST   15

D   14
C   13
B   12
A   11

R34
10K

5   GND
6   GND
9   GND
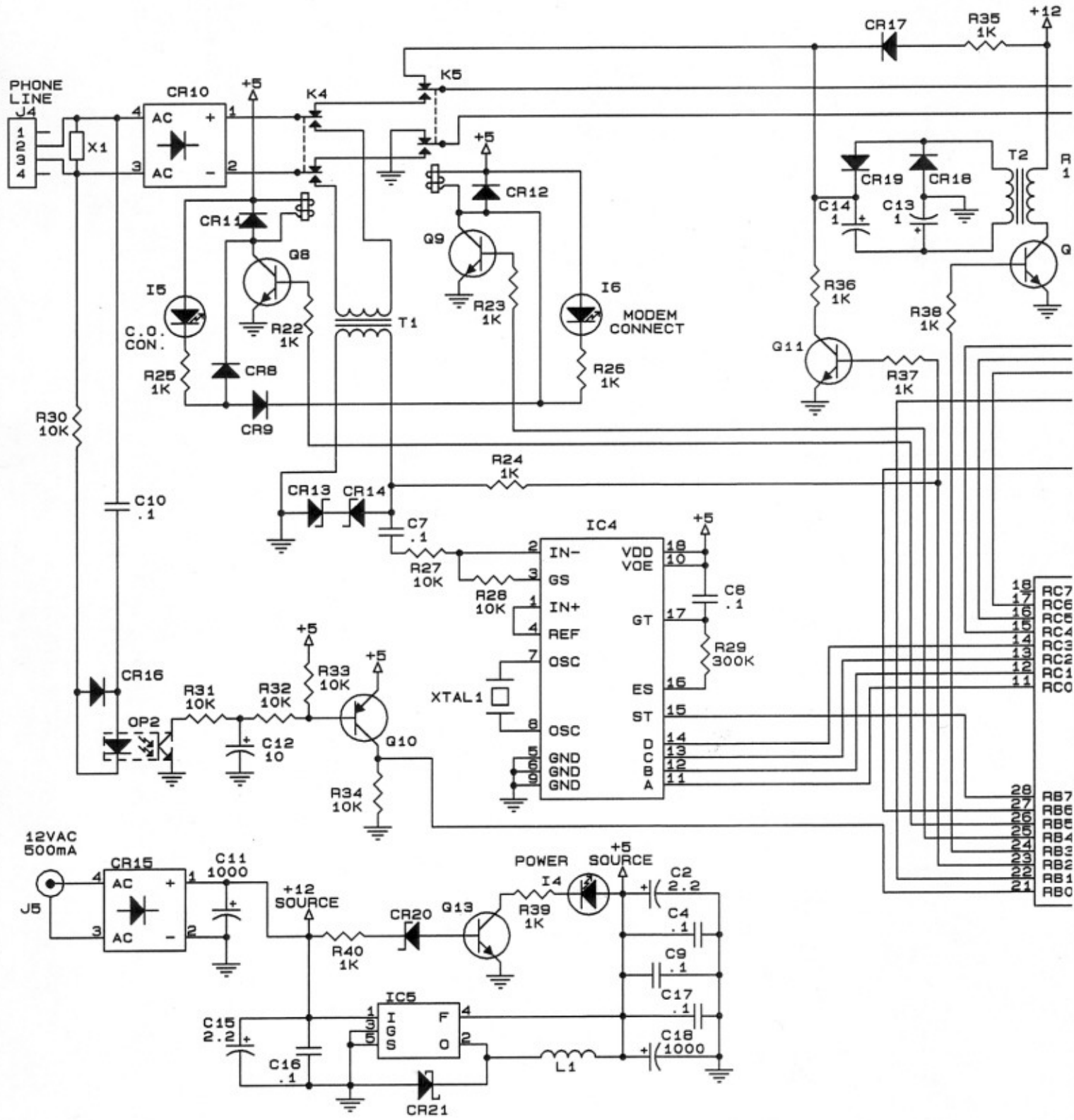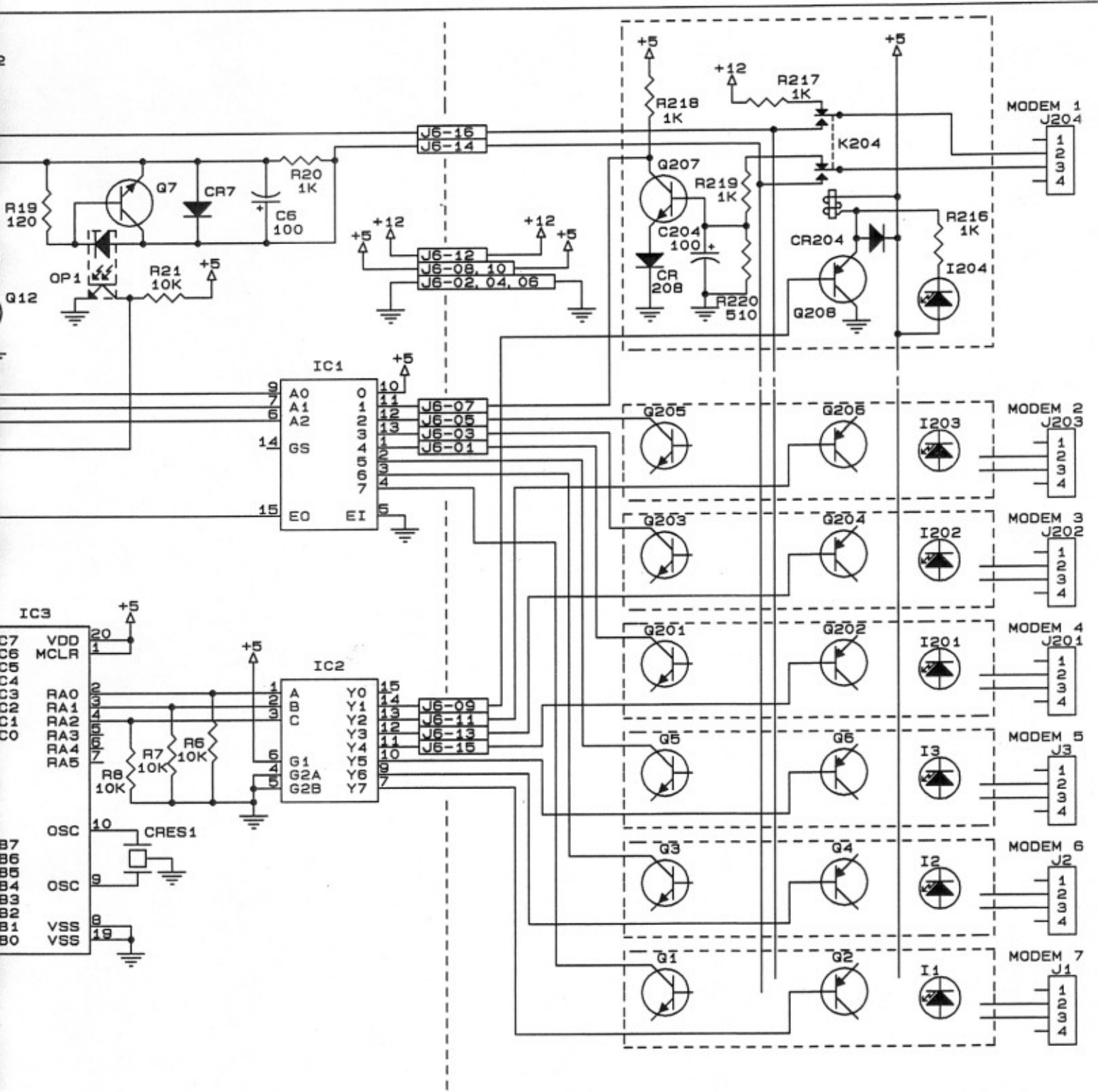
18 RC7
17 RC6
16 RC5
15 RC4
14 RC3
13 RC2
12 RC1
11 RC0

28 RB7
27 RB6
26 RB5
25 RB4
24 RB3
23 RB2
22 RB1
21 RB0

12VAC
500mA

CR15
AC +
4   1
3   2
AC −

J5

C11
1000

+12 SOURCE

CR20   Q13

POWER +5 SOURCE

I4

C2
2.2

R39
1K

C4
.1

R40
1K

C9
.1

C15
2.2

IC5

1   I   F   4
3   G
5   S   O   2

C17
.1

C16
.1

CR21

L1

C18
1000

MODEM 1
J204

MODEM 2
J203

MODEM 3
J202

MODEM 4
J201

MODEM 5
J3

MODEM 6
J2

MODEM 7
J1

+5
+12
R217 1K
R218 1K
R219 1K
R216 1K
R220 510
K204
Q207
C204 100
CR208
CR204
Q208
I204

J6-16
J6-14

R19 120
Q7
CR7
C6 100
R20 1K
OP1
R21 10K
Q12
+5

+5 +12   +12 +5
J6-12
J6-08, 10
J6-02, 04, 06

IC1
A0 9
A1 7
A2 5
GS 14
EO 15
0 10
1 11
2 12
3 13
4
5
6
7
EI

J6-07
J6-05
J6-03
J6-01

IC3
C7 VDD 20
C6 MCLR 1
C5
C4 RA0 2
C3 RA1 3
C2 RA2 4
C1 RA3 5
C0 RA4 6
    RA5 7
B7 OSC 10
B6
B5 OSC 9
B4
B3 VSS 8
B2
B1 VSS 19
B0

CRES1

R7 10K   R6 10K
R8 10K

IC2
A 1
B 2
C 3
G1 6
G2A 4
G2B 5
Y0 15
Y1 14
Y2 13
Y3 12
Y4 11
Y5 10
Y6 9
Y7 7

J6-09
J6-11
J6-13
J6-15

Q205   Q206   I203
Q203   Q204   I202
Q201   Q202   I201
Q5   Q6   I3
Q3   Q4   I2
Q1   Q2   I1

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