STEPHENS ENGINEERING ASSOCIATES, INC

1612

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AUTOMATIC ANTENNA COUPLER

SEA 1612

INSTRUCTION MANUAL

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1612

TABLE OF CONTENTS

FIGURES

1. GENERAL INFORMATION

1.1 OVERALL DESCRIPTION

The SEA 1612 is a fully automatic antenna coupler, designed for a wide range of applications. The SEA 1612 features an advanced microprocessor based tuning algorithm which allows this antenna coupler to tune up on normal voice signals from the transmitter, and also contains a "learning" algorithm which allows the control computer to remember which network constants are required for a given operating frequency. This feature permits the antenna coupler, once the "learning" operation is completed, to retune a given frequency in approximately 20 milliseconds. This is less than the time required to say "hello". The coupler operation is completely automatic and requires no operator intervention. If the antenna system is altered or replaced, the coupler will automatically "relearn" the required constants. During the learning period, operation is somewhat slower and, depending on the particular frequency/antenna combination, up to 5 seconds may be required to achieve a matched condition. Once the antenna is properly matched, the coupler signals this condition by pulling a control line low. This control signal may be used to operate an "all tuned" indicator at the operator's T-R position.

1.2 ELECTRICAL CONFIGURATION

The coupler matches the antenna by selecting the proper network from a possible combination of 64 values of input C, 32 values of output C, and 256 values of series L. Network configuration is automatically determined during the tune cycle and may be either a Pi network or either of two types of L network. Whenever possible, the L network will be selected for maximum efficiency. Tuneup is entirely automatic and is accomplished on voice signals, making it unnecessary to provide a "low power tune" mode in the transmitter. The use of a -20 dB coupler in the VSWR sensors allows the error detectors to function down to power levels of 5 to 10 watts. This allows the use of radio equipment which has "high VSWR shutdown" circuitry.

1.3 MECHANICAL CONFIGURATION

The circuitry of the SEA 1612 is divided into two printed circuit boards, one containing the RF circuitry and control computer, the other containing the frequency counter circuitry. The Frequency Counter PC Board is plugged into the Main Board with two connectors. Removal of the Frequency Counter PC Board will automatically deactivate the "learning" mode and will cause the antenna coupler to revert to a normal "tune on interrupt" mode. That is, any time the load VSWR exceeds 4:1, the coupler will go through the tuneup algorithm.

1.4 WEATHER HOUSING

The SEA 1612 antenna coupler is housed in a weatherproof fiberglas case designed to withstand the environmental conditions encountere aboard ship when mounted on the weather decks. The internal construction is designed to withstand the shock and vibration of mari service. Corrosion-resistant hardware and passivated alloys are employed throughout.

2. SPECIFICATIONS

Frequency Range	1.6 to 25.0 MHz
RF Power Capability	150 watts peak envelope power (PEP)
Input Impedance	50 ohms
VSWR	2:1
Power Requirements	13.6 VDC
Operating Current	2 Amps
Tuning Time	"Learn Mode", typically less than 5 seconds, "Educated Mode", approximately 20 milliseconds.
Antenna Required	Marconi type with suitable RF ground. See installation instructions for details.
Mounting	Any position
Environmental Temp. Range	-30°C to +60°C
Size	15" x 12" x 5.5"
Weight	10 lbs./4.5 kgs.
Case Construction	Waterproof, Fiberglass
Control Cable	#20 Gauge, 3 or 4 wires 3 or 4 Conductor #20 Shielded

3. PARTS FURNISHED

3.1 Antenna Coupler with cover and bushings.

3.2 Instruction Manual.

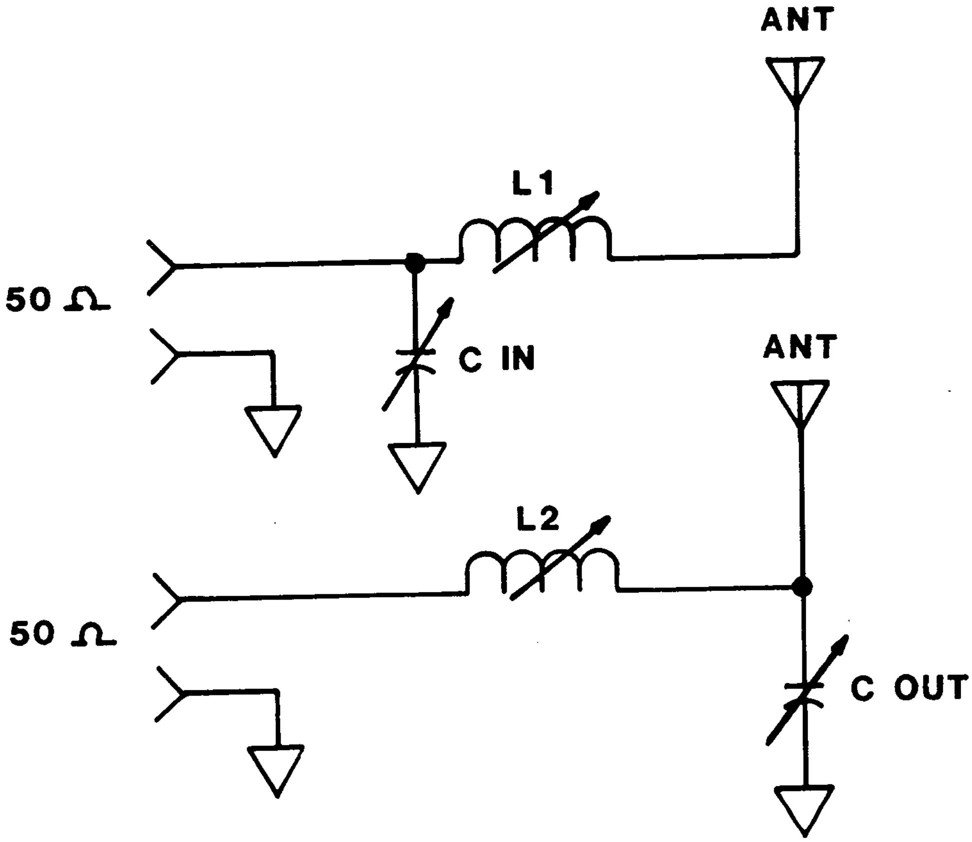
4. PRINCIPLE OF OPERATION

4.1 NETWORKS

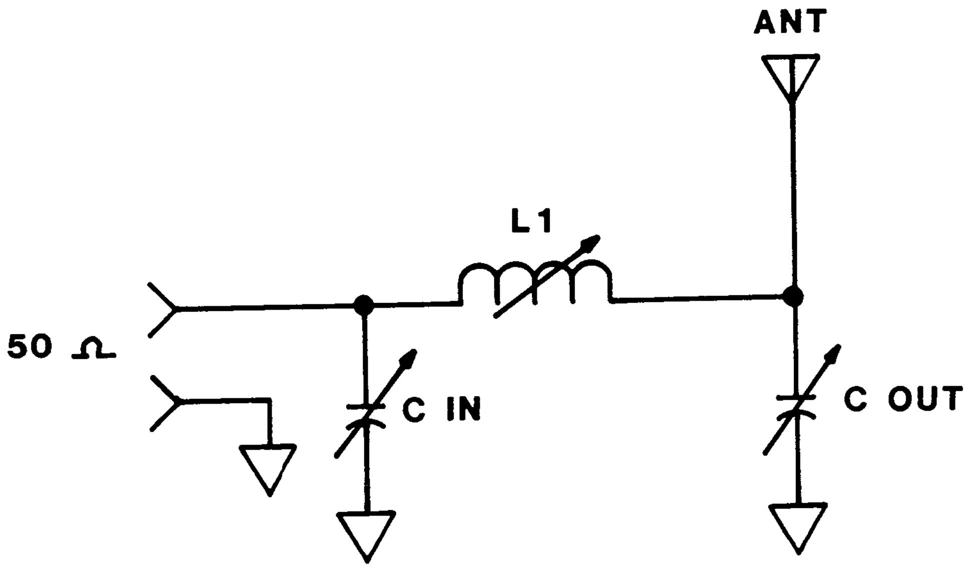
Figure 4.1 shows the schematic diagram for the two basic network configurations. Note that the "L" network as viewed from the generator may be configured as either "C in" or "C out", whichever is required by the load. In either case, the end of the network containing the shunt C element will be the HIGHER impedance end of the network.

4.2 SCHEMATIC DIAGRAMS

Figures 5.1 and 5.2 are the schematic diagrams of the antenna coupler. RF input is applied to UHF fitting J1, 13.6 VDC is connected to the terminals marked "-" and "+" on TB1, and an appropriate antenna and ground system are connected to feedthrough insulator and stainless steel stud respectively. The "ALL TUNED" flag line on TB1 is connected to the remote indicator device used.



The "L" Network



The "π" Network

FIGURE 4.1
NETWORK CONFIGURATIONS

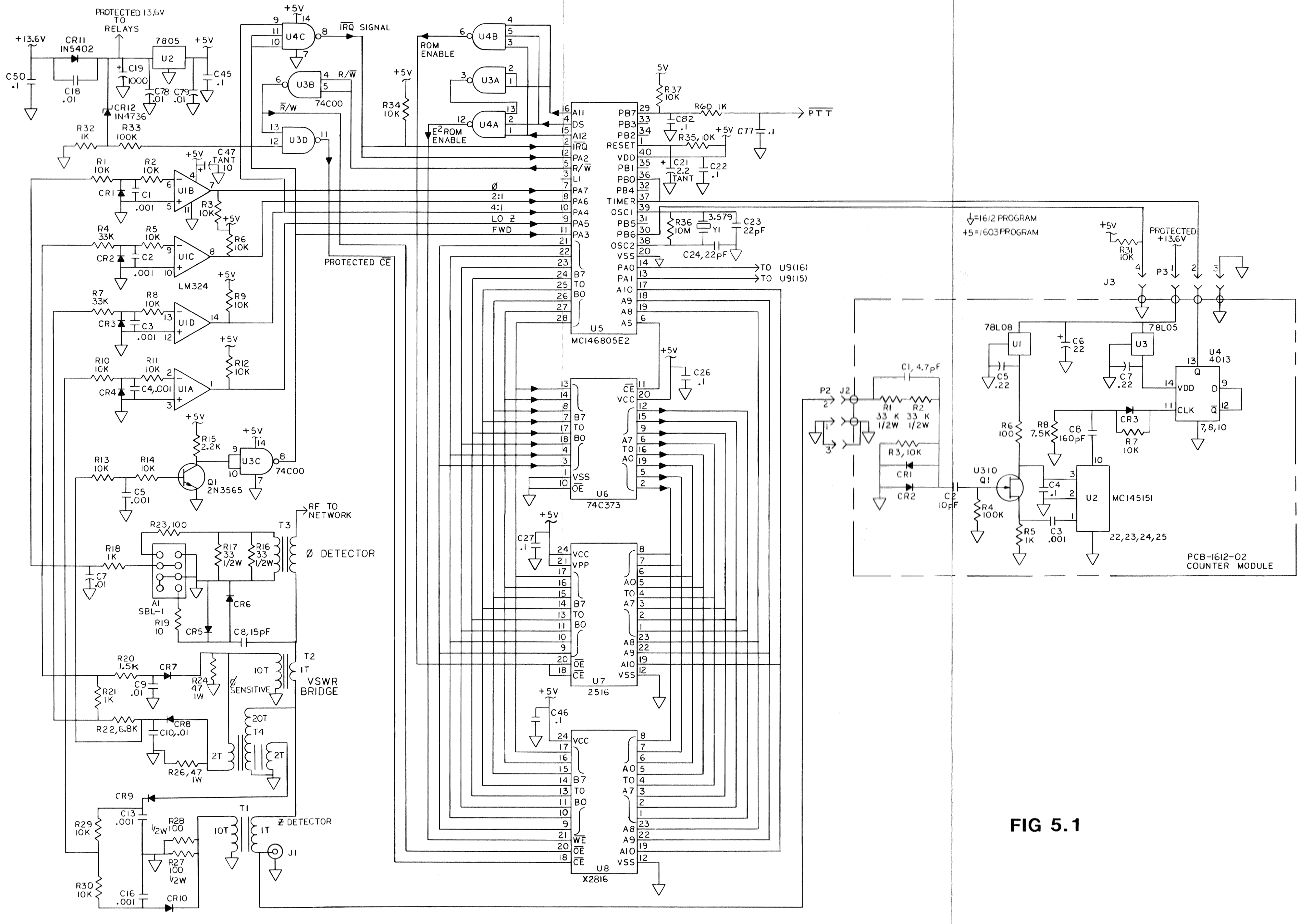
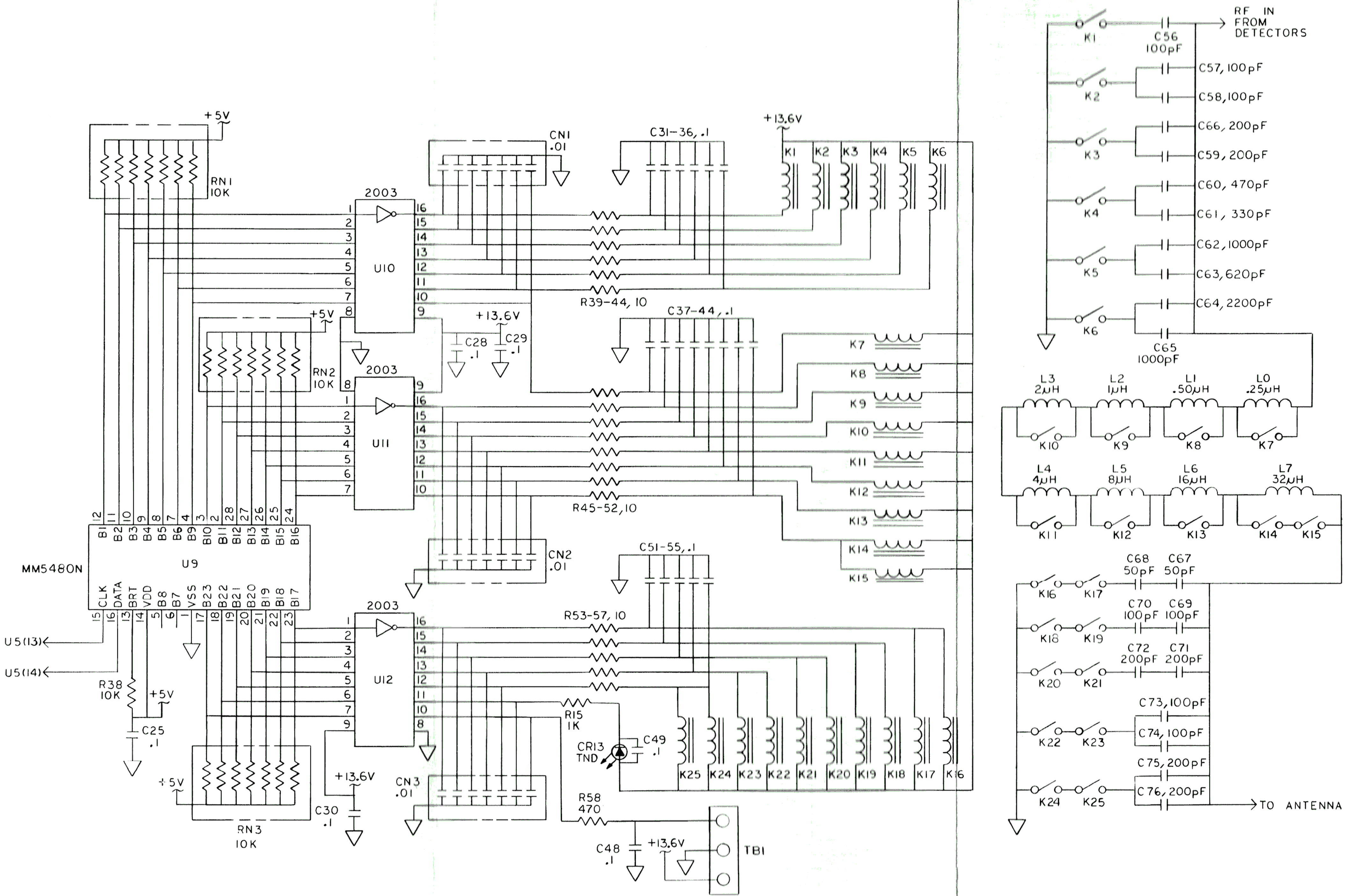
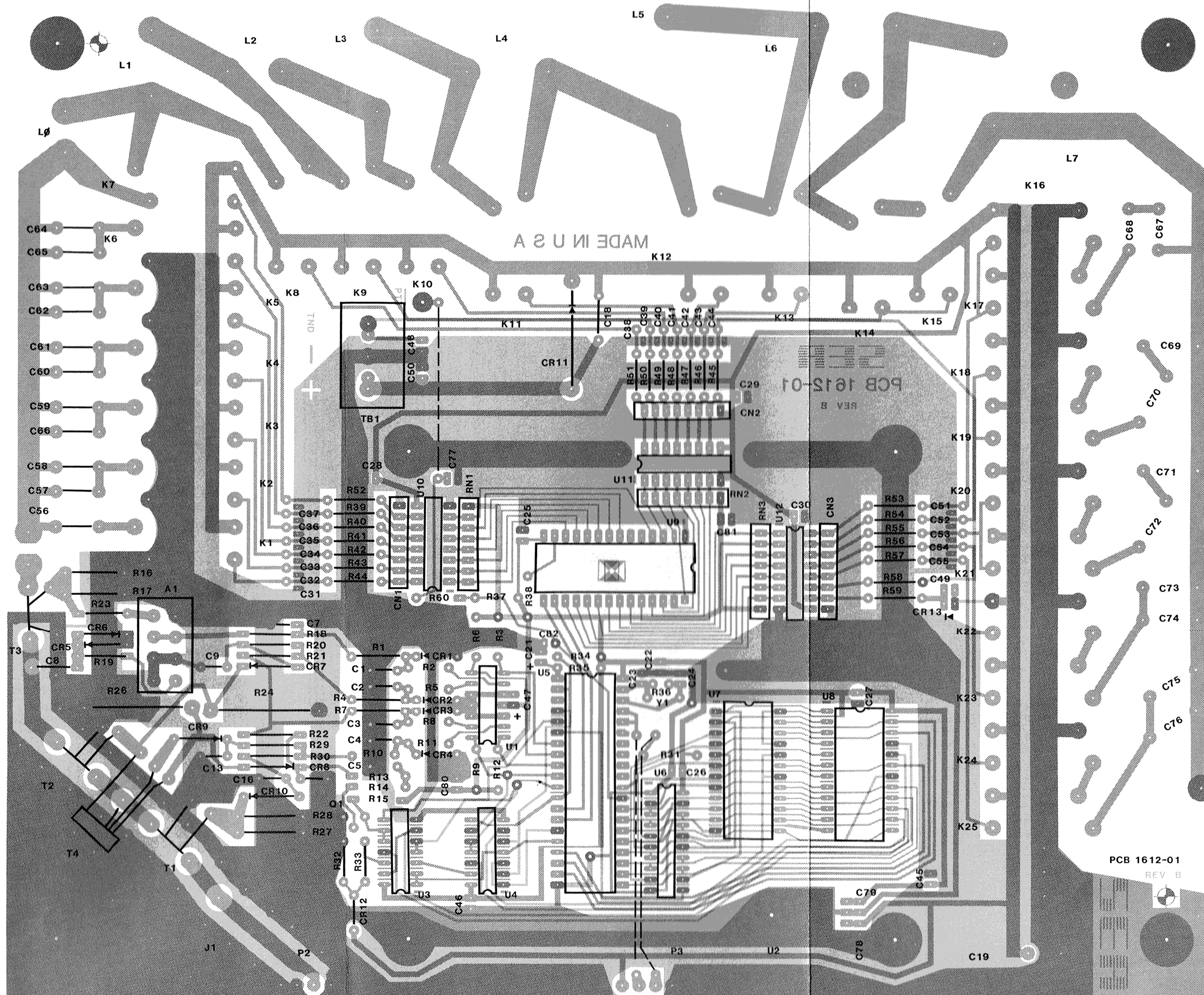

PROTECTED 13.6V TO RELAYS
+13.6V
CR11 IN5402
7805
U2
+5V
C50 .1
C18 .01
C19 1000
C78 .01
C79 .01
C45 .1
CR12 IN4736
R32 1K
R33 100K
U4C
IRQ SIGNAL
U3B
R/W
74C00
U3D
U4B
U3A
U4A
ROM ENABLE
E2ROM ENABLE
R34 10K
R37 10K
R60 1K
PTT
C82 .1
R35, 10K
C77 .1
C21 2.2 TANT
C22 .1
R36 10M
3.579 Y1
C23 22pF
C24, 22pF
TO U9(16)
TO U9(15)
U5
MC146805E2
C47 TANT 10
R1 10K
R2 10K
U1B
CR1
C1 .001
R3 10K
R4 33K
R5 10K
U1C
CR2
C2 .001
R6 10K
LM324
R7 33K
R8 10K
U1D
CR3
C3 .001
R9 10K
R10 1CK
R11 10K
U1A
CR4
C4,.001
R12 10K
Ø
2:1
4:1
LO Z
FWD
PROTECTED CE
R15 2.2K
U3C
74C00
R13 10K
R14 10K
Q1 2N3565
C5 .001
RF TO NETWORK
T3
Ø DETECTOR
R23,100
R17 33 1/2W
R16 33 1/2W
R18 1K
C7 .01
A1 SBL-1
CR6
R19 10
CR5
C8,15pF
T2
VSWR BRIDGE
R20 1.5K
CR7
C9 .01
R24 47 1W
Ø SENSITIVE
R21 1K
R22,6.8K
CR8
C10,.01
20T
T4
2T
R26,47 1W
CR9
C13 .001
R28 100 1/2W
R27 100 1/2W
R29 10K
R30 10K
C16 .001
CR10
T1
Z DETECTOR
J1
C26 .1
U6
74C373
C27 .1
U7
2516
C46 .1
U8
X2816
↓=1612 PROGRAM
+5=1603 PROGRAM
R31 10K
PROTECTED +13.6V
J3
P3
P2
J2
78L08
U1
C6 22
78L05
U3
U4 4013
C5 .22
C7 .22
C1, 4.7pF
R1 33 K 1/2W
R2 33 K 1/2W
R3, 10K
CR1
CR2
C2 10pF
U310 Q1
R4 100K
R6 100
R8 7.5K
C8 160pF
CR3
R7 10K
C4 .1
C3 .001
R5 1K
U2
MC145151
22,23,24,25
PCB-1612-02 COUNTER MODULE

FIG 5.1



RF IN FROM DETECTORS
TO ANTENNA
MM5480N
U9
U10
U11
U12
2003
RN1 10K
RN2 10K
RN3 10K
+5V
+13.6V
CN1 .01
CN2 .01
CN3 .01
C31-36, .1
C37-44, .1
C51-55, .1
R39-44, 10
R45-52, 10
R53-57, 10
R15 1K
R38 10K
R58 470
C25 .1
C28 .1
C29 .1
C30 .1
C48 .1
C49 .1
CR13 TND
TB1
U5(13)
U5(14)
CLK
DATA
BRT
VDD
VSS
C56 100pF
C57, 100pF
C58, 100pF
C66, 200pF
C59, 200pF
C60, 470pF
C61, 330pF
C62, 1000pF
C63, 620pF
C64, 2200pF
C65 1000pF
L3 2μH
L2 1μH
L1 .50μH
L0 .25μH
L4 4μH
L5 8μH
L6 16μH
L7 32μH
C68 50pF
C67 50pF
C70 100pF
C69 100pF
C72 200pF
C71 200pF
C73, 100pF
C74, 100pF
C75, 200pF
C76, 200pF

FIG 5.2



PCB 1612-01
REV B
MADE IN U S A
L0
L1
L2
L3
L4
L5
L6
L7
K1
K2
K3
K4
K5
K6
K7
K8
K9
K10
K11
K12
K13
K14
K15
K16
K17
K18
K19
K20
K21
K22
K23
K24
K25
TB1
CN1
CN2
CN3
RN1
RN2
RN3
U1
U2
U3
U4
U5
U6
U7
U8
U9
U10
U11
U12
A1
T1
T2
T3
T4
J1
P2
P3
Q1
Y1
CR1
CR2
CR3
CR4
CR5
CR6
CR7
CR8
CR9
CR10
CR11
CR12
CR13

FIG 6.1

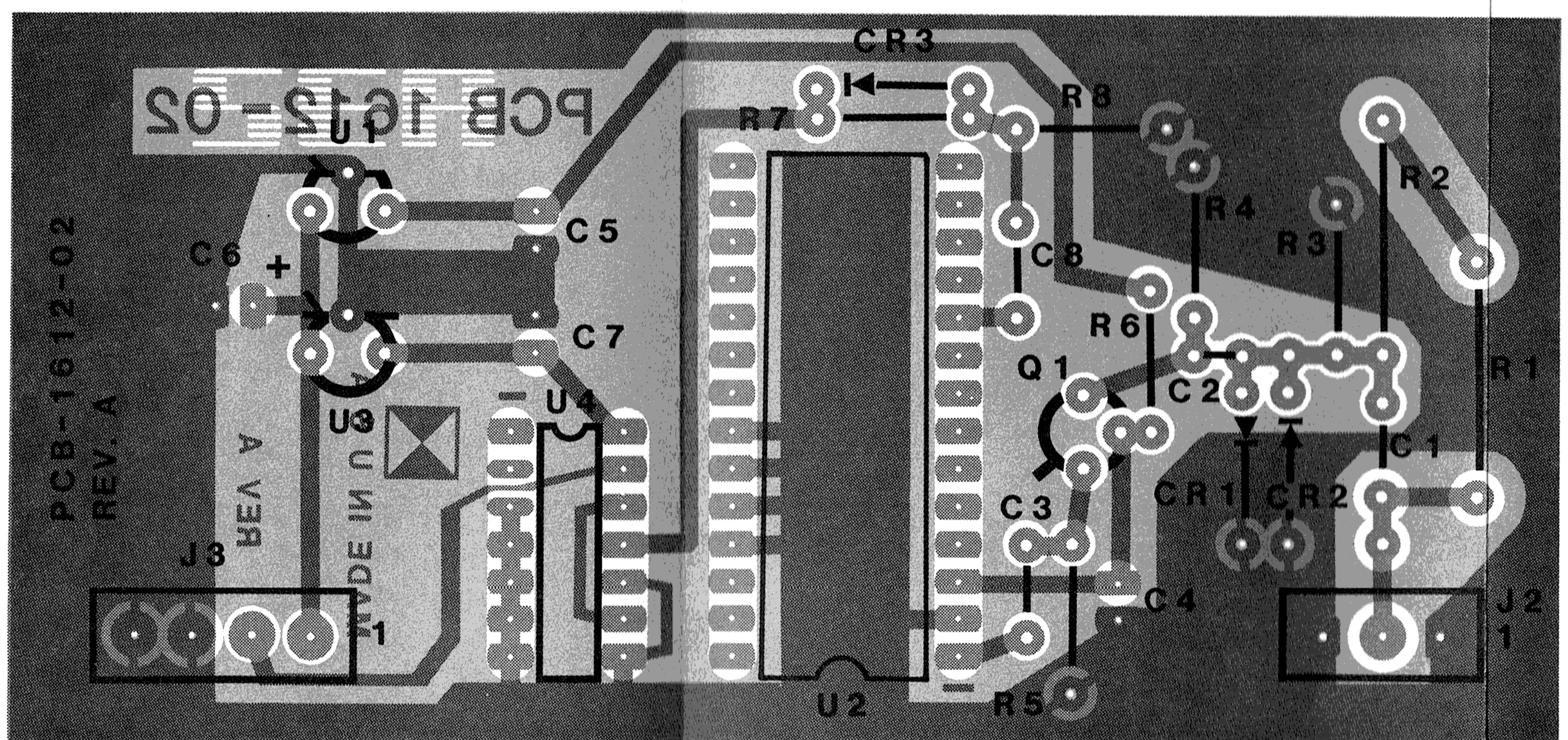

PCB 1612-02
PCB-1612-02
REV. A
CR3
R7
R8
U1
C5
C6
+
C7
U3
U4
R4
R2
R3
R6
R1
Q1
C2
C8
C1
CR1
CR2
C3
C4
J3
J2
1
U2
R5
MADE IN U.S.A.
REV A

FIG 6.2

4.3 AUTO TUNE OPERATION

When RF power is applied to the antenna coupler, it is first passed through an array of detector devices which determine the antenna system impedance, reactance sign, and the load VSWR. Forward power is also monitored, since the control computer requires an indication of both forward and reflected power in order to allow tuning to proceed. In practice, the forward power detector is used by the computer as a truth check to insure that the measurements made are indeed a result of applied RF and not spurious levels from the data conversion system. Tuneup will ONLY proceed when sufficient forward power is present to provide this truth check. After passing through the detector system, the RF is applied to the tuner array. This consists of 6 capacitors in shunt on the input arm of the network, arranged in binary increments, 8 inductors in the series arm, arranged in binary increments, and 5 more capacitors in shunt on the output arm, also arranged in binary increments. Relays are provided in conjunction with each lumped constant which allow removal or entry as desired. Thus, it is possible through the manipulation of 25 relays to build a network having 64 values of input shunt C, 32 values of output shunt C, and up to 256 values of series L.

4.4 IMPEDANCE DETECTOR

T1 and the components associated with it form an impedance bridge which is balanced at 50 ohms. T1 samples the line current and thus CR10 outputs a negative DC level proportional to line current. A tertiary winding on transformer T4 provides a line voltage sample to CR9, which provides a positive voltage proportional to line voltage. R29 and R30 act as a summing network for the current and voltage signals. Transformer turns ratios on T1 and T4 are chosen such that at 50 ohms, the summed signals result in a balanced or zero voltage condition. Should the line impedance go HIGH, the signal from the VOLTAGE sensor will be relatively higher than the CURRENT sensor, thus resulting in a net POSITIVE output voltage from the summing network. Similarly, a LOW line impedance will result in more output from the CURRENT sensor, resulting in a net NEGATIVE output voltage from the summing network. The summing network output is applied to U1A which operates as a ground referenced comparator.

4.5 VSWR DETECTOR

Current transformer T2 and voltage transformer T4, in conjunction with termination resistors R24 and R26 make up a 20 dB dual directional coupler. This directional coupler is inserted in the 50 ohm transmission line between the input connector, J1, and the tuning network. A sample of FORWARD power appears across termination R24. As in the impedance sensor previously described, the R samples are detected by diodes which are polarized to provide a POSITIVE output on FORWARD power and a NEGATIVE output on any REFLECTED power. A summing network consisting of resistors R20, R21, and R22 combine the signals from the forward and reflected power detectors. The values of these summing resistors are chosen to provide voltage levels which bear a certain relationship to specific reflection conditions "seen" by the dual directional coupler. Specifically, the junction of R20 and R21 will go NEGATIVE when load VSWR exceeds 2:1, while the junction of R21 and R22 will go NEGATIVE when load VSWR exceeds 4:1. The 2:1 VSWR signal is connected to U1C, another comparator. The 4:1 VSWR signal is connected to U1D. Note that the full output from the FORWARD power detector is connected through transistor inverter Q1 to U3C, a CMOS gate connected as an inverter. It is permissible to eliminate a comparator on the FORWARD sensor line since this signal is typically much larger in amplitude than the output signals from the summing network.

4.6 PHASE DETECTOR

T3, A1 and the associated components form a phase detector which indicates the state of any reactance associated with the antenna/coupler as seen from the generator. Operationally, a line current sample is compared in phase with a voltage sample in a double balanced mixer. Output polarity is POSITIVE for a net CAPACITIVE reactance. The ouptut of the phase detector, A1 is connected to comparator U1B.

4.7 THE CONTROL COMPUTER

Actual antenna matching is implemented though a tuneup algorithm contained in the memory provided in the computer system. The computer itself is designed around the CMOS MC146805E2 CPU. This device was chosen for its versatile instruction set and on-chip clock and RAM. Control of the antenna coupler relays is done through U9, an MM5480 LED driver. In this application, the MM5480 is used as a serial to parallel interface port. The CLOCK and DATA inputs of the MM5480 are driven from CPU ports PA1 and PA0, respectively. In operation, data is transferred into the CPU under program control from the array of sensor/comparators. Essentially, the program monitors the status of the input sensors and, starting from a present condition status, manipulates the RF elements through its control algorithm to achieve a correctly tuned condition. At the completion of the tuning algorithm, the computer generates a table in non-volatile memory which correlates the status of the various network relays with the applied RF frequency. This table is stored in EEPROM U8 and is used to provide the exclusive "learning" feature in the SEA 1612. After storing and latching the network status, the CPU returns to the "STOP" mode and waits for another "TUNE REQUEST" condition. When a "TUNE REQUEST"is received, the first step in the control algorithm is to measure the frequency of the signal which has generated the request. From the frequency data, the computer then looks into the table stored in U8 for any frequency/network status which may be stored. If data is found, it is immediately tested. If the data is valid, the required "end of tune" conditions will be sensed by the RF sensors, the data will be latched in place, and the CPU will again return to the "STOP" mode. This process takes about the same length of time that is required to close the network relays, or about 20 milliseconds.

4.8 INITIALIZATION AND FIREUP

Since any microcomputer generates RF noise while running, it is normally in the "STOP" mode and requires an interrupt signal to start program implementation. This IRQ signal is derived from the RF sensor network as follows: The positive output from the FORWARD power detector is buffered through Q1 and U3C and applied as a positive logic "1" to NAND gate U4C. Also applied to U4C is a signal from the 4:1 VSWR comparator, U1D. Since the 4:1 comparator input goes NEGATIVE when input VSWR exceeds 4:1, and since comparator U1D inverts this signal, the resultant output to NAND gate U4C is also a logic "1". This pair of logical "1"s on gate U4C will result in a logical "0" at the output. This output is directly connected to the IRQ request input of the CPU and will cause the computer to come alive and, after the preliminary initialization process, begin to implement the control algorithm.

4.9 INFORMATION READ

The data sensors (previously described) are interfaced with the CPU through input ports PA3 through PA7. Once the tune algorithm is running (following an interrupt request as outlined above and lacking any applicable prestored data) the program can access any desired variable by merely "looking" at the desired input port. Since the comparators effectively preprocess the desired data, "reading" any specific variable requires only that the program "look" at the required port as that variable is desired.

4.10 INFORMATION WRITE

When the CPU requires a change in the lumped RF tuner parameters, it writes the desired data into the series to parallel buffer, U9. This is done by outputting the desired status of the network relays in a serial data stream from PA0 on the CPU. Clocking is derived from PA1. For example, it is desired at some point in the tuneup sequence to INCREASE the inductance by one binary increment. To accomplish this, the CPU examines the binary number representing the status of the L control relays, decrements that number by one and clocks that number one bit at a time into the register in U9. (Note that in order to INCREASE the inductance it is necessary to DECREASE the binary number in the CPU register. This is due to the fact that a data 1 equals a CLOSED relay which equals a shorted inductor. In a similar fashion, the CPU is able to control the bits which control the input and output C banks.)

4.11 THE PROGRAM

The control algorithm is contained in EPROM U7. The actual program consists of many subroutines and branch statements in "machine language" for the MC146805E2. For that reason, no detailed treatment of the program will be given here. A general understanding of the process employed may be had by examination of the key steps the program makes in determining the lumped constants required to tune a 25 foot antenna (for example) at a frequency of first 4 MHz and then 1.6 MHz. In the 4 MHz case, upon sensing that both forward and reflected power exist, the program will first examine the EEPROM table for applicable data. In the event that no previously stored data is found, or that any such data is tested and found incorrect, the program will initiate a tuneup sequence by setting the initial conditions (all lumped constants out). By examination of the phase detector the determination is made that the antenna is short (capacitive) at the drive frequency, and so series L is inserted in lumps until the phase detector indicates that the load is no longer capacitive. At this point the program branches and measures the impedance. It will generally be low at this time and if so, the program increments the input C while manipulating series L to simultaneously raise the input impedance and maintain a resistive match. Once the impedance has nulled, the VSWR is examined and, if satisfactory, the network data is stored against an address determined by the frequency measurement already made and stored. The program is then terminated. If, in the previous example, it is impossible to normalize the reactance of the antenna with the available supply of L (possible at 1.6 MHz), a branch in the program will increment the output C and search the L again, continuing in this fashion until the phase detector indicates that the load is resistive. It will then measure the input impedance and proceed as before. The difference is that now the network will be a Pi network instead of the original L network. Additional subroutines are included in the program which set various "breakpoints" in the allowable constants as a complex function of frequency. In fact, the overall "program" actually consists of a program set which is designed to allow maximum flexibility while still maintaining high operating speed. With the addition of the onboard memory and frequency counter, many more complex programming techniques are possible, adding greatly to the actual complexity of the program.

Another unique feature of the SEA 1612 is the "DUPLEX" operating mode. This mode is provided in order to allow the operator to elminate the large loss in receiving sensitivity which can occur when the SEA 1612 (or any antenna coupler for that matter) is used in the 2-3 MHz spectrum. The sensitivity loss occurs as a result of the relatively narrow bandwidth of the matching network when used with short antennas. Remember that the coupler responds to TRANSMITTER frequencies on tuneup and so acts as a narrowband preselector filter at the transmitter frequency. Normally, this creates no problem, but in special cases, particularly when the antenna system is short, the ground system good, and the receiver frequency is far removed from the transmitter frequency, considerable loss in receiver sensitivity can result. The problem is especially acute when the wide split puts the receiver frequency on the "high side", since the tuning network is generally configured as a low pass filter. The "DUPLEX" mode makes use of a special control algorithm which, when energized, senses the RECEIVE mode as an absence of forward power from the sensor and, after a short delay, switches out all tuning elements. This connects the antenna directly to the input of the receiver and, while the receiver input will not be "matched" to the antenna, a substantial increase in overall sensitivity will generally result. When the forward power sensor again indicates transmitter operation, the coupler will revert to the previously stored tune data.

In order to utilize the DUPLEX operating mode, the extra pin type connector near TB1 and K10 must be returned to ground. This may be done internally or through use of an extra control switch at the operator's T-R position.

5. INSTRUCTION PROCEDURE

5.1 MECHANICAL CONSIDERATION

The SEA 1612 requires only that a source of 13.6 VDC, an RF transmission line (RG-58/U up to 30 feet, RG-8/U over 30 feet) and a suitable antenna/ground system be attached. No bandswitch information, low power tune, or "handshake" is required to the RF generator, since the coupler tunes on voice signals. Power consumption is nominally less than 1 amp, allowing the use of light 2 or 3-conductor cable for reasonable run lengths. (NOTE: The third conductor in the power cable is to provide for an "ALL TUNED" indicator flag when this is desired.) The power terminal of the SEA 1612, TB1, is clearly marked for polarity and the entire coupler is protected against reverse polarity connection by series diode CR11. Weatherdeck mounting is permitted for the SEA 1612 but years of marine experience indicate that inside mounting or even just splash-protected mounting is to be preferred, particularly in cold, damp environments.

The base of the antenna should be connected to the high voltage feedthrough insulator on the top of the SEA 1612 weather housing. Note that this insulator is not designed to support heavy mechanical loads. If such loading is encountered, the use of a strain insulator is desirable.

The ground system should be connected to the 1/4 inch stainless steel stud protruding from the bottom of the weather housing. Connection to the ground system and the ground system itself are of extreme importance for a successful installation. Ground runs of over a few inches should be made from 4-inch wide copper strap or better. The actual ground system should be as good as possible, and may consist of screening embedded in decks or roofs, coamings, rails, stack shrouds, water and/or fuel tanks, etc. Ships with a non-conducting structure, such as fiberglass, require careful attention to detail to provide an adequate ground system. Please note that this attention to ground integrity is NOT unique to the SEA 1612. ALL shipboard installations have the same requirements. However, autotune couplers in general require the antenna parameters to be within the range of the tuning parameters, or the coupler will not find a satisfactory match. It should always be remembered that the tiny computer in the SEA 1612 is unable to second-guess the installer! A PROPER ANTENNA/GROUND INSTALLATION IS OF PARAMOUNT IMPORTANCE!

5.2 ELECTRICAL CHECKOUT

After mechanical installation is completed, the SSB transmitter should be adjusted to the HIGHEST frequency desired, a directional wattmeter such as the BIRDtm Model 43 inserted into the transmission line, and the transmitter energized. Upon application of RF energy, the coupler should begin to tune, indicated by a general "clattering" of the PC mounted relays. If the antenna length and ground parameters are within range, a few syllables of speech should immediately cause the relay noise to cease, reflected power on the wattmeter to drop to a value consistent with a better than 2:1 VSWR and the PC mounted "TUNED" LED, CR13, to light. (If a remote "TUNED" indicator is provided, this indicator should also light.)

The SSB transmitter should now be adjusted to the LOWEST desired frequency, and the speech test repeated. Again, the SEA 1612 should immediately sense the mismatch, switch into the tune mode and retune the antenna system. The tune cycle will take somewhat longer at the lower frequencies, since the algorithm must search through more possible values of L and C to find an appropriate combination. A few seconds of speech should result in an "all tuned" indication. If the antenna parameters are within the specified range, and the above tests have been performed successfully, the SEA 1612 installation and tuneup may be considered complete.

Note that, as received, the memory system in the SEA 1612 will most likely NOT contain prestored data appropriate to your installation. For this reason, the memory feature will likely NOT be impressive at first. To allow the SEA 1612 to "learn" your antenna's requirements, simply proceed from frequency to frequency, allowing the normal tuneup to take place. As more and more frequencies are "memorized" by the computer, it should be possible to return to a previously used frequency and discover that the computer immediately flashes the "ALL TUNED" flag, usually before the first syllable is completed. It should be further noted that the EEPROM memory system is capable of storing hundreds of individual frequency/relay combinations but that most of these combinations are actually used in the first 4 or 5 MHz of operating frequencies. This is done in order to provide better memory resolution at the lower frequencies where antenna systems are inherently narrowband. Very often, one or two memory positions will give adequate band coverage at frequencies in the higher marine bands.

SEA 1612 PARTS LIST

PART NUMBER	DESCRIPTION
ASY-1601-07	BOX
ASY-1612-01	ANTENNA COUPLER
ASY-1612-02	COUNTER BOARD
BOX-0004-001	SHIPBOX,1010,1040,1050,1060
FAB-1612-01	RF SHIELD COVER
FAB-1612-02	BOTTOM PLATE
LBL-1010-001	DECAL, SEA FOR COUPLER
HAR-0073-001	MTG.POST,HEX THREAD 10-32
HAR-1000-001	10-32 STD HEX NUT
HAR-1000-002	#10 L/W
HAR-1000-250	10-32 1/4 HP PH M SCREW
MAN-1612	1612 MANUAL
BOX-0001-001	BOX,FIBERGLASS LG J1210W
FAB-0002-001	GROUND STRAP 1" BY 12"
HAR-0021-001	BUSHING
HAR-0021-002	BUSHING, SMALL
HAR-2500-001	1/4-20 NUT
HAR-2500-002	WASHER, 1/4" I.T.L.
HAR-2501-001	1/4-20x1.0
INS-0001-001	INSULATOR, ANTENNA

REFERENCE DESIGNATORS FOR ASY-1612-01 ANTENNA COUPLER

EFFECTIVE 12-20-83

REF DES	PART NUM	DESCRIPTION
A1	MIX-0002-001	GRADED MIXER
C1	CAP-0021-001	CAPACITOR DISC .001uf
C10	CAP-0017-001	CAPACITOR DISC .01uf
C13	CAP-0021-001	CAPACITOR DISC .001uf
C16	CAP-0021-001	CAPACITOR DISC .001uf
C18	CAP-0017-003	CAPACITOR DISC .01uf 500V
C19	CAP-0037-009	CAP.ELECT 1000UF RAD
C2	CAP-0021-001	CAPACITOR DISC .001uf
C21	CAP-0031-001	CAP TANT 2.2uf 16-25V
C22	CAP-0013-001	CAPACITOR MONO .1uf
C23	CAP-0001-003	CAPACITOR MICA 22pf
C24	CAP-0001-003	CAPACITOR MICA 22pf
C25	CAP-0013-001	CAPACITOR MONO .1uf
C26	CAP-0013-001	CAPACITOR MONO .1uf
C27	CAP-0013-001	CAPACITOR MONO .1uf
C28	CAP-0013-001	CAPACITOR MONO .1uf
C29	CAP-0013-001	CAPACITOR MONO .1uf
C3	CAP-0021-001	CAPACITOR DISC .001uf
C30	CAP-0013-001	CAPACITOR MONO .1uf
C31	CAP-0013-001	CAPACITOR MONO .1uf
C32	CAP-0013-001	CAPACITOR MONO .1uf
C33	CAP-0013-001	CAPACITOR MONO .1uf
C34	CAP-0013-001	CAPACITOR MONO .1uf
C35	CAP-0013-001	CAPACITOR MONO .1uf
C36	CAP-0013-001	CAPACITOR MONO .1uf
C37	CAP-0013-001	CAPACITOR MONO .1uf
C38	CAP-0013-001	CAPACITOR MONO .1uf
C39	CAP-0013-001	CAPACITOR MONO .1uf
C4	CAP-0021-001	CAPACITOR DISC .001uf
C40	CAP-0013-001	CAPACITOR MONO .1uf
C41	CAP-0013-001	CAPACITOR MONO .1uf
C42	CAP-0013-001	CAPACITOR MONO .1uf
C43	CAP-0013-001	CAPACITOR MONO .1uf
C44	CAP-0013-001	CAPACITOR MONO .1uf
C45	CAP-0013-001	CAPACITOR MONO .1uf
C46	CAP-0013-001	CAPACITOR MONO .1uf
C47	CAP-0031-005	CAPACITOR TANT 10uf 16V
C48	CAP-0013-001	CAPACITOR MONO .1uf
C49	CAP-0013-001	CAPACITOR MONO .1uf
C5	CAP-0021-001	CAPACITOR DISC .001uf
C50	CAP-0013-001	CAPACITOR MONO .1uf
C51	CAP-0013-001	CAPACITOR MONO .1uf
C52	CAP-0013-001	CAPACITOR MONO .1uf
C53	CAP-0013-001	CAPACITOR MONO .1uf
C54	CAP-0013-001	CAPACITOR MONO .1uf
C55	CAP-0013-001	CAPACITOR MONO .1uf
C56	CAP-0003-001	CAPACITOR DM19 100pf
C57	CAP-0003-001	CAPACITOR DM19 100pf
C58	CAP-0003-001	CAPACITOR DM19 100pf
C59	CAP-0003-021	CAPACITOR DM19 200pf

REFERENCE DESIGNATORS FOR ASY-1612-01 ANTENNA COUPLER

EFFECTIVE 12-20-83

REF DES	PART NUM	DESCRIPTION
C6	CAP-0001-003	CAPACITOR MICA 22pf
C60	CAP-0003-004	CAPACITOR DM19 470pf
C61	CAP-0003-003	CAPACITOR DM19 330pf
C62	CAP-0003-006	CAPACITOR DM19 1000pf
C63	CAP-0003-014	CAPACITOR DM19 620pf
C64	CAP-0003-010	CAPACITOR DM19 2200pf
C65	CAP-0003-006	CAPACITOR DM19 1000pf
C66	CAP-0003-021	CAPACITOR DM19 200pf
C67	CAP-0050-050	CAPACITOR, 50pf 5KV RMC
C68	CAP-0050-050	CAPACITOR, 50pf 5KV RMC
C69	CAP-0050-100	CAPACITOR, 100PF 5KV RMC
C7	CAP-0017-001	CAPACITOR DISC .01uf
C70	CAP-0050-100	CAPACITOR, 100PF 5KV RMC
C71	CAP-0050-200	CAPACITOR, 200PF 5KV RMC
C72	CAP-0050-200	CAPACITOR, 200PF 5KV RMC
C73	CAP-0050-100	CAPACITOR, 100PF 5KV RMC
C74	CAP-0050-100	CAPACITOR, 100PF 5KV RMC
C75	CAP-0050-200	CAPACITOR, 200PF 5KV RMC
C76	CAP-0050-200	CAPACITOR, 200PF 5KV RMC
C77	CAP-0013-001	CAPACITOR MONO .1uf
C78	CAP-0013-003	CAPACITOR MONO .01uf 100V
C79	CAP-0013-003	CAPACITOR MONO .01uf 100V
C8	CAP-0007-003	CAPACITOR DM15 15pf
C80	CAP-0013-001	CAPACITOR MONO .1uf
C81	CAP-0013-001	CAPACITOR MONO .1uf
C82	CAP-0013-001	CAPACITOR MONO .1uf
C9	CAP-0017-001	CAPACITOR DISC .01uf
CN1	CAP-0060-103	CAPACITOR, NETWORK .01uf
CN2	CAP-0060-103	CAPACITOR, NETWORK .01uf
CN3	CAP-0060-103	CAPACITOR, NETWORK .01uf
CR1	SEM-0076-001	DIODES 1N4148
CR10	SEM-0076-001	DIODES 1N4148
CR11	SEM-0089-001	1N5402
CR12	SEM-0170-026	IN4736A
CR13	SEM-0084-001	LED, RED
CR2	SEM-0076-001	DIODES 1N4148
CR3	SEM-0076-001	DIODES 1N4148
CR4	SEM-0076-001	DIODES 1N4148
CR5	SEM-0076-001	DIODES 1N4148
CR6	SEM-0076-001	DIODES 1N4148
CR7	SEM-0076-001	DIODES 1N4148
CR8	SEM-0076-001	DIODES 1N4148
CR9	SEM-0076-001	DIODES 1N4148
J1	CON-0007-002	CONNECTOR UHF SO239
K1	REL-0007-001	RELAY, SPST 12VDC
K10	REL-0007-001	RELAY, SPST 12VDC
K11	REL-0007-001	RELAY, SPST 12VDC
K12	REL-0007-001	RELAY, SPST 12VDC
K13	REL-0007-001	RELAY, SPST 12VDC
K14	REL-0007-001	RELAY, SPST 12VDC

REFERENCE DESIGNATORS FOR ASY-1612-01 ANTENNA COUPLER

EFFECTIVE 12-20-83

REF DES	PART NUM	DESCRIPTION
K15	REL-0007-001	RELAY, SPST 12VDC
K16	REL-0007-001	RELAY, SPST 12VDC
K17	REL-0007-001	RELAY, SPST 12VDC
K18	REL-0007-001	RELAY, SPST 12VDC
K19	REL-0007-001	RELAY, SPST 12VDC
K2	REL-0007-001	RELAY, SPST 12VDC
K20	REL-0007-001	RELAY, SPST 12VDC
K21	REL-0007-001	RELAY, SPST 12VDC
K22	REL-0007-001	RELAY, SPST 12VDC
K23	REL-0007-001	RELAY, SPST 12VDC
K24	REL-0007-001	RELAY, SPST 12VDC
K25	REL-0007-001	RELAY, SPST 12VDC
K3	REL-0007-001	RELAY, SPST 12VDC
K4	REL-0007-001	RELAY, SPST 12VDC
K5	REL-0007-001	RELAY, SPST 12VDC
K6	REL-0007-001	RELAY, SPST 12VDC
K7	REL-0007-001	RELAY, SPST 12VDC
K8	REL-0007-001	RELAY, SPST 12VDC
K9	REL-0007-001	RELAY, SPST 12VDC
L0	ASY-1612-L0	INDUCTOR, 0.025uh
L1	ASY-1612-L1	INDUCTOR, 0.50uh
L2	ASY-1061-L2	INDUCTOR, 1.0uh
L3	ASY-1061-L3	INDUCTOR, 2.0uh
L4	ASY-1061-L4	INDUCTOR, 4.0uh
L5	ASY-1061-L5	INDUCTOR, 8uh
L6	ASY-1612-L6	INDUCTOR, 16uh
L7	ASY-1061-L7	INDUCTOR, 32uh
P2	CON-0024-011	MOLEX 3 PIN PLUG
P3	CON-0024-019	MOLEX 4 PIN PLUG
Q1	SEM-0001-001	2N3565
R1	RES-0001-103	RESISTOR 10K 1/4W
R10	RES-0001-103	RESISTOR 10K 1/4W
R11	RES-0001-103	RESISTOR 10K 1/4W
R12	RES-0001-103	RESISTOR 10K 1/4W
R13	RES-0001-103	RESISTOR 10K 1/4W
R14	RES-0001-103	RESISTOR 10K 1/4W
R15	RES-0001-222	RESISTOR 2.2K 1/4W
R16	RES-0002-330	RESISTOR, 33 1/2W
R17	RES-0002-330	RESISTOR, 33 1/2W
R18	RES-0001-102	RESISTOR 1K 1/4W
R19	RES-0001-100	RESISTOR 10 1/4W
R2	RES-0001-103	RESISTOR 10K 1/4W
R20	RES-0001-222	RESISTOR 2.2K 1/4W
R21	RES-0001-102	RESISTOR 1K 1/4W
R22	RES-0001-682	RESISTOR 6.8K 1/4W
R23	RES-0001-101	RESISTOR 100 1/4W
R24	RES-0006-473	RESISTOR, 47K 1W
R26	RES-0001-470	RESISTOR 47 1/4W
R27	RES-0002-101	RESISTOR, 100 1/2W
R28	RES-0002-101	RESISTOR, 100 1/2W

REFERENCE DESIGNATORS FOR ASY-1612-01 ANTENNA COUPLER

EFFECTIVE 12-20-83

REF DES	PART NUM	DESCRIPTION
R29	RES-0001-103	RESISTOR 10K 1/4W
R3	RES-0001-103	RESISTOR 10K 1/4W
R30	RES-0001-103	RESISTOR 10K 1/4W
R31	RES-0001-103	RESISTOR 10K 1/4W
R32	RES-0001-102	RESISTOR 1K 1/4W
R33	RES-0001-104	RESISTOR 100K 1/4W
R34	RES-0001-103	RESISTOR 10K 1/4W
R35	RES-0001-103	RESISTOR 10K 1/4W
R36	RES-0001-106	RESISTOR 10MEG 1/4W
R37	RES-0001-104	RESISTOR 100K 1/4W
R38	RES-0001-103	RESISTOR 10K 1/4W
R39	RES-0001-100	RESISTOR 10 1/4W
R4	RES-0001-333	RESISTOR 33K 1/4W
R40	RES-0001-100	RESISTOR 10 1/4W
R41	RES-0001-100	RESISTOR 10 1/4W
R42	RES-0001-100	RESISTOR 10 1/4W
R43	RES-0001-100	RESISTOR 10 1/4W
R44	RES-0001-100	RESISTOR 10 1/4W
R45	RES-0001-100	RESISTOR 10 1/4W
R46	RES-0001-100	RESISTOR 10 1/4W
R47	RES-0001-100	RESISTOR 10 1/4W
R48	RES-0001-100	RESISTOR 10 1/4W
R49	RES-0001-100	RESISTOR 10 1/4W
R5	RES-0001-103	RESISTOR 10K 1/4W
R50	RES-0001-100	RESISTOR 10 1/4W
R51	RES-0001-100	RESISTOR 10 1/4W
R52	RES-0001-100	RESISTOR 10 1/4W
R53	RES-0001-100	RESISTOR 10 1/4W
R54	RES-0001-100	RESISTOR 10 1/4W
R55	RES-0001-100	RESISTOR 10 1/4W
R56	RES-0001-100	RESISTOR 10 1/4W
R57	RES-0001-100	RESISTOR 10 1/4W
R58	RES-0001-471	RESISTOR 470 1/4W
R59	RES-0001-102	RESISTOR 1K 1/4W
R6	RES-0001-103	RESISTOR 10K 1/4W
R60	RES-0001-103	RESISTOR 10K 1/4W
R7	RES-0001-333	RESISTOR 33K 1/4W
R8	RES-0001-103	RESISTOR 10K 1/4W
R9	RES-0001-103	RESISTOR 10K 1/4W
RN1	RES-0028-002	RESISTOR 10K 8 PIN RN
RN2	RES-0028-002	RESISTOR 10K 8 PIN RN
RN3	RES-0028-002	RESISTOR 10K 8 PIN RN
T1	ASY-1612-T1	TRANSFORMER Z
T2	ASY-1612-T2	TRANSFORMER VSWR
T3	ASY-1612-T3	TRANSFORMER PHASE
T4	ASY-1612-T4	TRANSFORMER
TB1	TER-0026-001	TERMINAL, 3 POS WEIDMEYER
U1	SEM-0154-001	LM324 OPAMP
U10	SEM-0151-003	ULN2003
U11	SEM-0151-003	ULN2003

REFERENCE DESIGNATORS FOR ASY-1412-01 ANTENNA COUPLER

EFFECTIVE 12-20-83

REF DES	PART NUM	DESCRIPTION
U12	SEM-0151-003	ULN2003
U2	SEM-0109-001	UA7805CKC
U3	SEM-0112-001	74C00 (RED)
U4	SEM-0170-016	MM74C10 (RED)
U5	SEM-0161-001	MC146805E2 (RED)
U6	SEM-0155-001	74C373 (RED)
U7	SEM-0108-003	TMS2516 MSM2716AS
U8	SEM-0170-012	X2816AD-45
U9	SEM-0170-017	MM5480N (RED)
Y1	CRY-0011-002	COLORBURST 3.579545 HC/18U

REFERENCE DESIGNATORS FOR ASY-1612-02 COUNTER BOARD

EFFECTIVE 12-20-83

REF DES	PART NUM	DESCRIPTION
C1	CAP-0002-018	CAP 4.7PF TUB-CERAMIC 10%
C2	CAP-0001-001	CAPACITOR MICA 10pf
C3	CAP-0021-001	CAPACITOR DISC .001uf
C4	CAP-0013-001	CAPACITOR MONO .1uf
C5	CAP-0013-002	CAPACITOR MONO .22UF 50V
C6	CAP-0037-001	CAP. ELECT 22UF RAD
C7	CAP-0013-002	CAPACITOR MONO .22UF 50V
C8	CAP-0001-018	CAPACITOR MICA 160pf
CR1	SEM-0076-001	DIODES 1N4148
CR2	SEM-0076-001	DIODES 1N4148
CR3	SEM-0076-001	DIODES 1N4148
J2	CON-0024-010	MOLEX 3 PIN JACK
J3	CON-0024-018	MOLEX 4 PIN JACK
Q1	SEM-0017-002	U310
R1	RES-0002-333	RESISTOR, 1/2W 33K
R2	RES-0002-333	RESISTOR, 1/2W 33K
R3	RES-0001-103	RESISTOR 10K 1/4W
R4	RES-0001-104	RESISTOR 100K 1/4W
R5	RES-0001-102	RESISTOR 1K 1/4W
R6	RES-0001-101	RESISTOR 100 1/4W
R7	RES-0001-103	RESISTOR 10K 1/4W
R8	RES-0001-752	RESISTOR 7.5K 1/4W
U1	SEM-0170-014	78L08
U2	SEM-0061-001	MC145151 (RED)
U3	SEM-0170-015	LM78L05AWC
U4	SEM-0140-013	4013 (RED)