Communications Research Centre

DUAL TONE MULTI-FREQUENCY (DTMF) AUTOMATIC RADIO TELEPHONE INTERCONNECT (RTI) SYSTEMS

by

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(Radar and Communications Technology Branch)

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ABSTRACT

New technology offers several approaches and opens the door to the development of improved VHF/UHF-FM or HF-SSB radio communications. These can range from simple improvements, employing new equipment and techniques to sophisticated integrated systems utilizing automation to reduce operator work load, or to eliminate the need for an operator at the base station. The concept of automatic connectivity to other radio systems, to private lines or to the switched public telephone system greatly increases the reliability and availability of radio communications. Selective calling relieves the user of the need for radio listening skills and the fatigue of manually monitoring HF channels. VHF/UHF-FM repeater systems employing radio telephone interconnection (RTI) are being employed by radio amateurs, by the telephone companies, and by commercial companies, and while such systems provide useful mobile communications to distances reached by mountain-top repeaters (60—100 kilometres or more depending on the height of the repeater), HF must be employed for the greater distances, and to date, RTI has not been possible at HF employing SSB transmission.

This report describes R and D carried out at the Communications Research Centre and in Canadian Industry during the past 5 years to develop simple, inexpensive RTI systems that could be employed to improve communications from the trail and from remote camps by northern and native people. The research has culminated in the development and field trial of prototype systems which it is hoped will lead to design/manufacture of suitable equipment so that systems adapted to provide the kind of service desired by users are available for purchase. The report is intended to serve as an introduction to repeater remote control; to dual-tone multi-frequency (DTMF) tone signaling for both FM and SSB signaling systems; and to radio telephone interconnect (RTI) systems.

1. INTRODUCTION

The concept of a VHF/HF-SSB system with automatic connectivity to other radio systems, to private lines or to the switched public telephone system is very attractive, especially for northern and remote communications, c.f. Belrose and Bode[1]. Selective calling relieves the user of the need for radio listening skills and the fatigue caused by manually monitoring noisy channels. In addition, for communications from and within northern and remote regions where, conventionally, a radio operator listens only during certain hours of the day, selective calling without the assistance of a radio operator means that the radio circuit is potentially available 24 hours per day for emergency use. Selective calling through an automatic base station is particularly important when the mobile unit is operating with battery powered equipment, since the "answer-back" feature of an automatic system lets the mobile operator know immediately that he has or has not achieved interconnection.

For HF radio where the propagation medium is variable, the mobile radio operator does not waste time and battery power uselessly calling. If he can't get through, he waits and tries again later when propagation conditions may have improved.

While VHF radio telephone interconnect (RTI) systems are available and require no hardware development for implementation, this report will describe nevertheless a simple VHF system that has been in operational use for 4 years with little or no problem. This will provide an introduction to repeater remote control, dual-tone multi-frequency (DTMF) signaling and to radio telephone interconnection methods. The main purpose of this report is to describe an adaptation of such a DTMF signaling system for use with SSB suppressed carrier equipment. The absence of a carrier complicates switching, and the frequency stability of portable units precludes the use of DTMF tone signaling in the conventional manner.

When the research described herein was begun, there were no known SSB radio-to-telephone interconnect systems, but selective call systems were available (e.g., the SE-IX encoder/SD-VI Decoder manufactured by Lorain Electronics Corp.*), and other systems have been developed during the course of our work (e.g., Transworld Electronics, Inc. S3/S3M selective call system). On completion of the R&D described in this report, a digital radio-to-telephone interconnect system for citizen's band (CB) radio and a response organization for motorist aid use has been described by Wallace[2]. It is very interesting to note that some of the features of the design of the CB digital system are similar to the analogue (DTMF tone-signaling) system described in our report. The CB radio-to-telephone interconnect system described by Wallace is not a user dial system, it is an autodial system in which interconnection is made to one telephone.

2. DTMF TECHNOLOGY

2.1 DTMF TONE SIGNALING

From the inception of automatic dialing, signaling from telephone instruments was accomplished using DC pulses (dial pulses). This is not a strictly correct terminology since the "dial pulse" opens the circuit, causing an interruption of current through the central office relays, rather than closing them with a burst of current as might be implied by "dial pulses". One pulse is sent from a rotary dial for the digit one and ten pulses for the digit 10 or 0. This signaling method requires direct wire connections as a DC path is needed. For transmission over a radio link, the DC pulses have to be converted to a keyed audio tone or tones.

VHF and UHF FM radio telephone systems currently in use, e.g., the MTS and IMTS (Mobile Telephone System and Improved Mobile Telephone System) employ two sequential tones (600 and 1500 Hz). The change in frequency from one tone to the other is detected as a dial pulse.

In the 1960s, the Bell Telephone companies (actually AT&T) introduced a new faster tone dialing system which was given the registered trade name Touch-Tone (TM). Because the tone signals of a TT system could be transmitted over any radio circuit and since TT equipment is readily available employing state-of-the-art technology (developed for telephone company requirements), it is clear that DTMF tone signaling adapted for radio transmission was the obvious route for inexpensive automatic RTI systems.

In high frequency (HF) single sideband systems the carrier is suppressed and either the upper or lower sideband frequencies are transmitted. When the carrier is re-introduced at the receiving station, errors of several tens or even hundreds of Hz can occur in the recovered audio modulating signal. Thus, the use of conventional touch-tones for dialing or switching was precluded initially in SSB systems.

With the further development of SSB technology, it became apparent that the problem could be overcome by transmitting dual-tones and taking their frequency difference; since both tones would be shifted in frequency by the same amount their difference would remain constant. The recovered single tones could then be used to regenerate standard touch-tones or dial pulses acceptable to the telephone system.

The RTI (Radio Telephone Interconnection) system described in Section 4 of this report utilizes a special tone format designed by the Communications Research Centre (CRC) in consultation with Baron Communications. The tone format in Table 1 is seen to consist of a pilot tone and sixteen information tones which are used for dialing and switching functions.

In the touch-tone (TM) system, information is coded in tone pairs using two of eight possible tones for the digits zero through nine, and six special functions #, *, A, B, C and D. The audio frequencies are given in Table 2.

2.2 ENCODERS

Early 12 button or 16 button encoders developed by the telephone companies (Automatic Electric or Western Electric) employed LC oscillators with a tapped inductor to generate the various frequencies. Currently available encoders developed during the course of our work employ a crystal reference encoder which utilizes a quartz crystal oscillator and a complex divider system to produce each of the required frequencies. The output synthesized tones are internally shaped in the special I.C.'s developed for these encoders into remarkably good sine waves. Two chips are currently available. They are the Motorola MC14410 IC which utilizes a 1 MHz crystal, and the Mostek MK 5086 IC which employs a 3.579545 MHz crystal. (The 3.58 MHz crystal used in colour TV sets is good enough.) External components are minimized requiring a crystal with a biasing resistor, two mixing resistors, a potentiometer to set the tone output level, and a coupling capacitor. See Figure 1 which is a typical circuit employed with the Mororola chip. The temperature stability is excellent and the encoder is relatively immune to radio frequency interference.

Many commercially manufactured encoders are available. The one shown in Figure 2 is a Drake Model 1525 EM microphone encoder which employs a Motorola chip, a 1.0 MHz crystal, a Digitron keyboard and a good quality low impedance microphone (500 ohms).

2.3 DECODERS

When investigations into automatic RTI systems were started at CRC in 1975, crystal reference tone receivers were not available. Typical circuitry employed at that time utilized active band pass filters or phase-locked loop (PLL) chips, such as the Signetics type NE-567; one to select each of the various tones. A typical circuit would employ two filters to separate the low and high frequency tone groups (so that separate AGC amplifiers could be employed), and a tone decoder (PLL chip or active filter) for each of the seven or eight tone frequencies.

TABLE 1

SSB Tone Signalling — Pilot Tone 2200 Hz

Touch Tone Digit	Information Tone (Hz)	Resultant Tone (Hz)
1	1879	321
2	1857	343
3	1833	367
4	1807	393
5	1780	420
6	1750	450
7	1719	481
8	1685	515
9	1649	551
0	1610	590
*	1569	631
#	1525	675
A	1478	722
B	1427	773
C	1373	827
D	1315	885

TABLE 2

Frequencies Used In Touch Tone Signalling Systems

Low Tone Group (Hz)	High Tone Group (Hz)			
	1209	1336	1477	1633
695	1	2	3	A
770	4	5	6	B
852	7	8	9	C
941	*	0	#	D

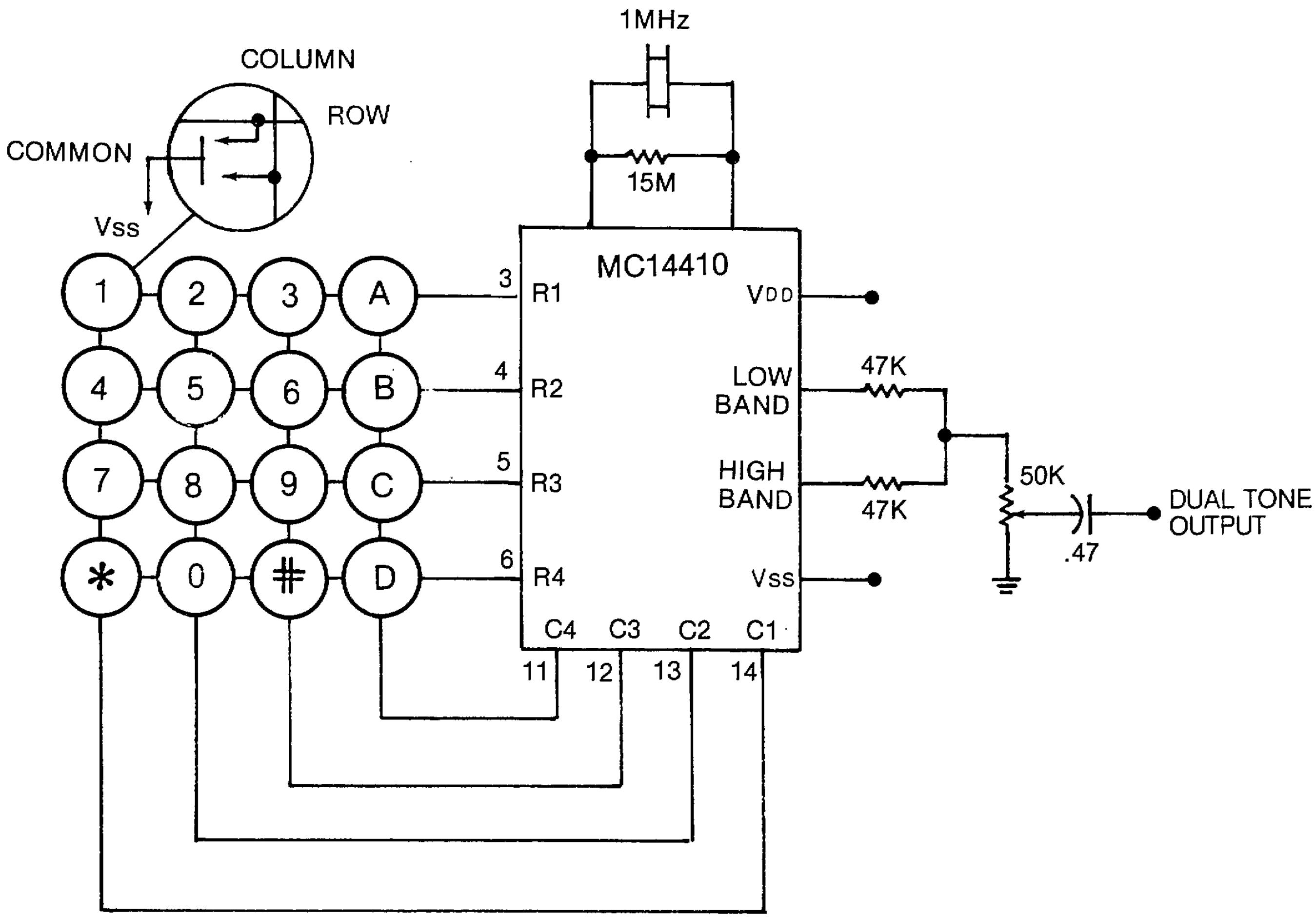


Figure 1. Typical Circuit for a Motorola Type 14410 IC

Figure 2. Drake Model 1525 EM Microphone-Encoder

To minimize falsing, circuit logic was designed to verify correct reception of a touch-tone; that is, only one output should be detected in the low tone group and only one in the high tone group, and these dual tones must be received simultaneously for a prescribed averaging time. The averaging times typically employed were 1/2 second for initial access and 50–150 milliseconds for normal dialing speed.

Recently a number of new special I.C.'s have been developed so that crystal reference tone decoders (or tone receivers) are available. Three such devices are the Mostek MK5102, the Mitel MH88210 and the versatile Intel 2920 Signal Processor Chip. The authors have no experience with these devices but for completeness, a brief description of each is given.

The MK5102 is a monolithic integrated circuit fabricated using complementary symmetry MOS (CMOS) process. It employs the inexpensive 3.579545 MHz television colour burst crystal for reference. The device detects the high and low group DTMF tones after band splitting using digital techniques. The zero crossings of the incoming tones are counted over several periods and the results averaged over a longer period. When a maximum of 40 milliseconds of valid DTMF digits is detected, the proper data is locked into the outputs and the output strobe goes high. When a valid digit is no longer detected, the strobe returns to low and the data remain latched into the outputs. Minimum interdigit time is 35 milliseconds. The MK5102 is designed to interface with a MK5098 Integrated Pulse Dialer, however, unless the initial dialing was done using a rotary dial telephone set, a first in first out memory (FIFO) must be employed otherwise the differences in timing between dial pulses and touch-tone digits will result in the dialing getting out of step. The Mostek MK50982 in fact incorporates in the one I.C. the required FIFO memory. The memory will store up to 17 digits and allows key strobed (touch-tone) digits to be entered at rates comparable to tone dialing telephones. Entering the first digit (except * and #) clears the memory buffer, and starts the outpulsing sequence. As additional digits are entered, they are stored in the memory and outpulsed in turn. The MK50982 also features a redial function. The stored number will be redialed if the first digit after "off-hook" is a * or # key input, provided that the circuit has been "on-hook" for a finite period.

Touch-tone digits can be touched out at several per second, (a rate of 10 per second is typically employed with automatic dialing equipment) whereas dial pulses are sent at the rate of 10 pulses per second. Hence, when employing dial pulses it takes 1/10 second to send the digit 1 but one second to send the digit 0.

The Mitel MH88210 requires no external components or tone filters. The unit is designed to accept standard DTMF tones and may be connected directly to the telephone line. The input signal is passed through a high-pass filter to provide dial tone rejection. High and low frequencies are separated by band splitting filters and squared off using a Schmitt trigger for each high and low tone group. These square waves are decoded by an averaging algorithm and after further signal processing, the digit is validated. On valid detection, an analogue guard tone circuit is activated on tone acquisition and release, preventing multiple digit recognition in the presence of impulse noise if the interruption is less than the allowable time drop out. The outputs are 2 of 8 octave high hexadecimal or 4 bit code.

The Intel 2920 DTMF receiver is perhaps the most sophisticated of the lot. The bandpass filters for the high and low tone groups are digital filters. Certainly, the device is the most versatile since by programming, it performs many signal processing functions. The DTMF receiver application requires 192 instructions. At the input of the DTMF receiver, the signal, after passing through an A/D converter is split by two very complex band splitting high pass and low pass digital filters. After splitting, they are passed through a limiter and four single pole band pass digital filters. The outputs of the band pass filters are full wave rectified and low pass filtered to extract the envelope. The envelope is passed through a level comparator to determine an on or an off condition. The combination of the limiter and the level comparator ensure that if more than one frequency passes through the high pass or the low pass section, none of the outputs will turn on. The output is a TTL compatible 2 of 8 code.

This completes the description of decoders. Further detail and actual circuitry for the simpler decoders employing PLL chips and band pass filters and separate circuit logic, FIFO memories etc. will be given later in the report.

3. A VHF AUTOPATCH REPEATER SYSTEM

Commercial VHF/UHF mobile radio systems having various degrees of complexity and employing microprocessor control are available. c.f. Francis[3] which describes the Glenayre Electronics, North Vancouver GL-1200 Radio Telephone Terminal. The microprocessor provides all control and supervisory functions as well as subscriber file management, billing data, etc.

Baron Communications, Vancouver have RTI systems of various complexity, e.g., their RTI-10. Both of these systems are designed to work with existing mobile radio telephone signaling systems such as MTS or IMTS (Mobile Telephone System or Improved Mobile Telephone System) employing two tone transitional change signals. That is, the unit detects the change in frequency between two tones sent sequentially (600 and

1500 Hz). One transition corresponds to the digit 1 and 10 transitions to the digit 0. The Mitel Corp., Ottawa, CM8390 Base Station Controller uses DTMF touch tone signaling which is much faster than the two tone sequential signaling.

3.1 GENERAL DESCRIPTION OF A SIMPLE AUTOPATCH SYSTEM

The block diagram of Figure 3 is the simplest possible VHF autopatch system employing a remote mountain-top repeater. That is, there are no decoders except for the * (star) and # (cross-hatch) functions, which are used for access and disconnection. A touch-tone line must be available, and automatic gain control (AGC) must be employed to regulate the amplitude of the received tones, but the decoding of the dialed telephone number is done by the telephone company's decoders. The system employs a UHF link so that the remote repeater can be located on a mountain or hilltop to increase the range of the repeater, but the telephone interconnection is made at some location in the city.

When a DTMF access signal * is transmitted from a mobile station, it is received by the VHF receiver at the mountain-top station. A DTMF decoder accepts a valid signal and closes a latch which enables the UHF transmitter. Signals following the initial access code will be re-transmitted on both the VHF and UHF transmitters. If no access code is transmitted by a mobile station, the UHF mountain-top transmitter remains on stand-by and the received signals are retransmitted on the VHF transmitter only.

If the access code has been sent, and the latch at the remote hilltop repeater is closed, the UHF down-link transmitter will transmit during the brief period that there is still a carrier-operated switching signal (COS) from the VHF receiver; that is, the mobile operator has not released his microphone switch after sending the digit *. This signal from the UHF down-link transmitter is received by the UHF up-link receiver at the base station, causing a latch to be set thereby closing relay RL2 which connects the phone line to the patch; i.e., the phone is lifted "off-hook". Since the latch at the hilltop is closed on the trailing edge of the digit *, there is no danger that this digit will enter the telephone line.

When the mobile operator releases his microphone PTT switch there is no COS signal from the VHF repeater receiver. The UHF down-link transmitter therefore reverts to the "off" condition since it is COS controlled, and the UHF down-link receiver is connected to the antenna. At the base station, the absence of the COS signal from the UHF up-link receiver opens relay RL1 which connects the telephone line switch to the audio input terminal of the UHF up-link transmitter, and turns on this transmitter. The dial tone is therefore transmitted by the UHF up-link transmitter.

This dial tone is received at the remote repeater site by the UHF down-link receiver, and rebroadcast by the VHF repeater transmitter so that the mobile operator hears the dial tone. He then presses his microphone button and touches out the 7 digit number he wishes to call. On receipt of his carrier by the VHF repeater receiver, switching reverses at the repeater site and the base station. The 7 digit DTMF sequence is transmitted by the UHF down-link transmitter, received by the UHF up-link receiver, and appears directly on the telephone line.

When the mobile operator completes dialing, he releases his microphone PTT switch. The absence of a COS signal from the VHF receiver again switches the system at the remote repeater and base station sites. The mobile operator therefore hears the telephone ringing and the subsequent answer of the called telephone party. He carries out a normal semi-duplex telephone conversation.

The UHF transmitter/receiver at the repeater site operates in simplex, but the UHF transmitter/receiver at the base station operates in duplex, even though the transmitter switches on and off as the telephone conversation proceeds. This is so that the mobile operator can control the switching; i.e., the UHF up-link receiver must be able to "hear" the signal from the UHF down-link transmitter, when the UHF up-link transmitter is on.

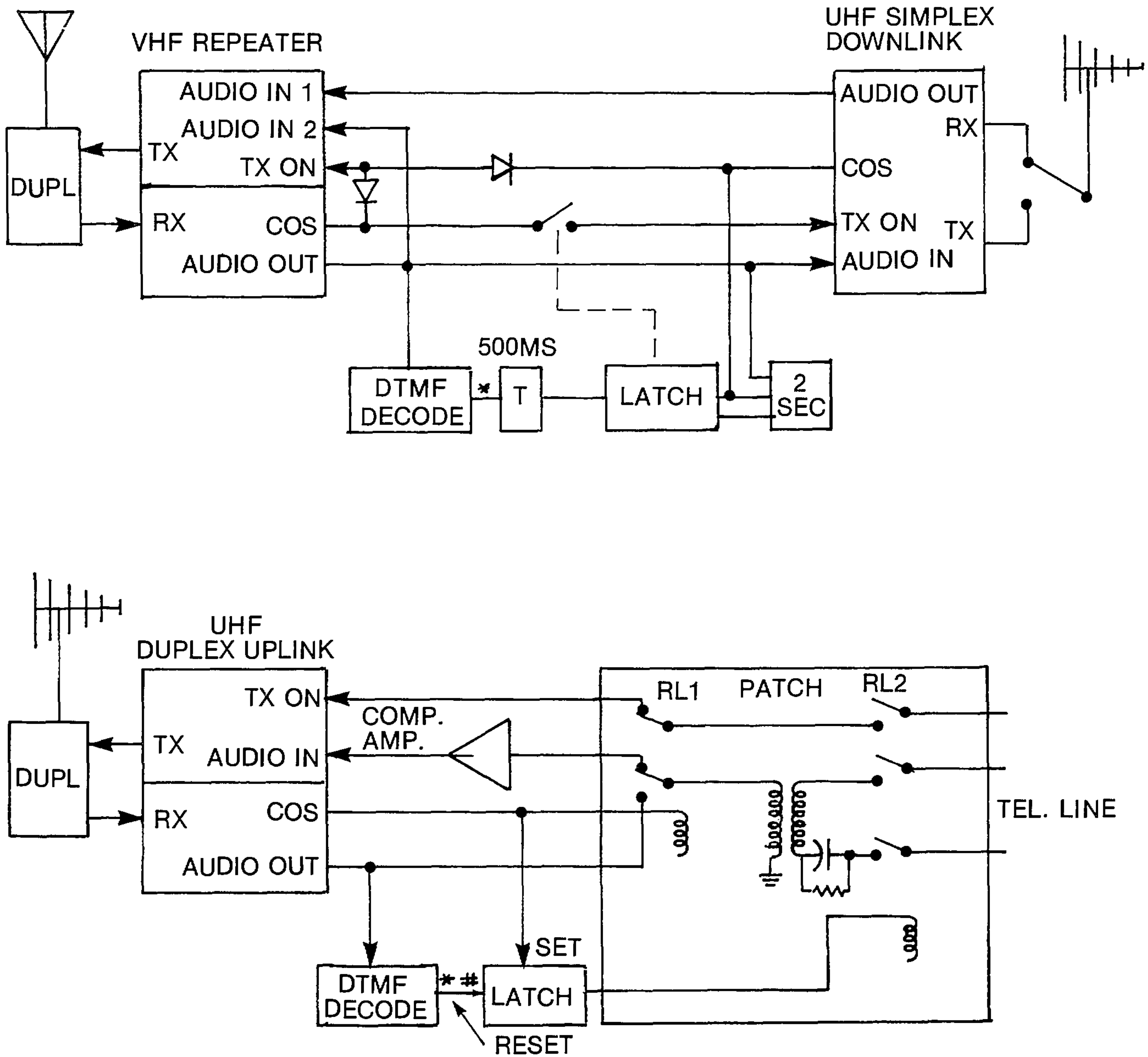


Figure 3. Block Diagram VHF Autopatch Repeater System

A two second link hold timer at the remote repeater site ensures that the latch does not open, as control switches from the COS output of the VHF receiver to the COS output of the UHF receiver.

On completion of the telephone conversation, the mobile operator sends the digit * and #, in sequence thereby resetting the latch at the base station. That is, relay RL1 opens which puts the phone "on-hook" and turns off the UHF up-link transmitter. When the mobile operator releases his microphone PTT switch, the absence of a carrier from the UHF down-link transmitter means that there is no COS signal from the UHF up-link receiver and the relay RL1 opens.

If there is no COS output from either the VHF or UHF receivers at the repeater site for a continuous 2 seconds, the 2 second timer times out thereby resetting the latch at the repeater site. The repeater is now available for normal mobile-to-mobile radio communication.

While this simple system was not used, it illustrates that a VHF repeater autopatch system can be very simple if a touch-tone line is available. A more practical repeater autopatch system requires additional control features such as timers, a time out beeper so that the mobile operator knows when automatic disconnect is going to happen, long distance (dial 1 as the first digit) disconnect so that long distance calls cannot be made, and etc., according to the user's requirements. Also, since direct connection of privately owned equipment to the telephone system is not permitted, interface to the telephone line must be through a telephone company voice station coupler.

The system to be described has been in operational use in the Ottawa area for 3 years. It employs a modified Data Signal Inc. Model RAP-400 Repeater Autopatch, and a Bell Canada type QCS Voice Station Coupler with options A, D and K; the options provide dialing capability, ring indication by closure of a contact on "RU1" or RU2" leads, and "off-hook" on "CT" and "CR" terminals. Since the RAP-400 unit contained its own decoders, with * for "off-hook" and # for "on-hook", an access code of * for one half second and * again at normal signaling speed was required for off-hook; and * and # in sequence was used for disconnect. Since resetting of the latch at the base station occurs on the trailing edge of the last digit in the *, # sequence, the # digit is also decoded by the RAP-400 unit causing the phone to be put "on-hook". An added feature of this more complex system is the ability to correct a misdialed number by pressing the # button and then the * button in sequence; this procedure hangs up the phone and then lifts it "off-hook" again without disconnecting the UHF link. The RAP-400 unit has the additional feature of reverse autopatch. Telephone calls directed to the base station telephone set trigger a ringing signal generator in the RAP-400 causing modulation of the UHF up-link transmitter. The signals are received at the hilltop repeater station, and when rebroadcast from the VHF transmitter alert mobile operators to the incoming call. If the mobile operator sends the access code in the usual manner he will complete the connection and "answer" the phone. A more complex system would employ decoders in the mobile transceivers so a particular mobile station could be called. The telephone caller would have to dial a 2 or 3-digit code, after "off-hook".

3.2 MOBILE EQUIPMENT

Any VHF—FM transceiver may be used in the mobile station. The DTMF tones are usually selected by a touch-tone microphone such as the Drake Model 1525EM shown in Figure 2. Frequency deviation on tones should be ± 1 kHz, and on voice ± 5 kHz peak.

3.3 MOUNTAIN-TOP EQUIPMENT

3.3.1 Duplexer

The duplexer used at the hilltop site was a Sinclair Radio Type Q-202-G designed for operation in the 148—174 MHz band. A frequency separation of 600 KHz is used between the transmit frequency of 147.36 MHz and the receive frequency of 147.96 MHz. The insertion loss is 1.5 dB and the isolation between receive and transmit ports is 80 dB.

3.3.2 VHF Transceiver

The VHF transceiver consists basically of a Motorola type CNRD 1132BB receiver and a CNTD 6122A transmitter together with additional control circuitry. The complete unit packaged as a mountain-top repeater is marketed by R.F. Electronics Ltd., Vancouver, under the model number BR-150-5 repeater series.

3.3.3 VHF Receiver/Control Section

The receiver control section is shown in schematic form in Figure 4.

3.3.3.1 Voltage Regulator

Battery supply voltage of minus 15 to 21V is fed to the regulator input from Pin 3 of P-801. The regulator employs the conventional feedback circuit and resistors R-605 and/or R606 are factory trimmed to provide an output of exactly 14V. Minimum input to output differential is 0.75V. At a remote repeater site caustic potash batteries would be employed; at a site where power is available, lead acid batteries on "float charge" would be used.

3.3.3.2 Carrier Operated Switches

The tie point "B" is connected to the junction of C-67 and R-53 in VHF receivers, or, in the case of UHF receivers, to the junction of a 560 ohm resistor and a 15 μfd capacitor added in series with the -14V supply to L-15, also designated R53 and C-67. In either case, the audio stages of the receiver are turned off during the absence of a carrier and no voltage drop exists across R-53, and therefore Q-604, Q-605 and Q-606 remain in the off condition. When a carrier is received the receiver squelch circuit will open turning the receiver audio stages on, and thereby establishing a voltage drop of approximately 3 volts across R-53. This will turn on Q-604 via R-608 and D-603 as well as Q-605 via R-609. The output of Q-604 is connected to pin 4 of J-601 to either control auxiliary equipment or, in the case of an isolated repeater, to turn on the repeater transmitter via a jumper from pin 4 to pin 5 of J-601.

3.3.3.3 Transmitter off Delay

In the case of a isolated repeaters or trunk drop repeaters, a circuit is provided to hold the repeater transmitter on the air for an adjustable period of 0.2 to 2 seconds after termination of a received carrier. This will bridge the gaps during average conversations and will also enable the mobile operator to determine whether or not he is activating the repeater transmitter. Turning on Q-605 will also turn on Q-606 via R-610. Q-606 will charge C-606 via D-604 and R-613. Upon termination of the carrier, Q-604 will lose its drive via R-608, but will be held on via R-612 for a period of time by the charge on C-606. This period can be adjusted by shunting C-606 with the variable resistor R-614.

For most trunk, point to point or back-to-back applications this feature is not required and in these cases, C-606 and R-614 are omitted.

3.3.3.4 Squelch Differential

In all VHF units, the DC supply to the RF amplifier of the receiver pre-selector is returned to ground via tie point "E" and R-616 and R-617, shunted by R-628. This will conserve battery drain in the stand-by condition and also provides a separate control of the turn-on threshold for the carrier operated switches. Once this threshold level has been exceeded and the squelch has opened, Q-606 will be turned on and the DC supply of the pre-selector will be returned to ground directly via D-605 and Q-606. By means of R-617 the "ON" threshold can be adjusted from 0.5 to 2.0 μv, whereas the "OFF" point remains fixed at 0.3 to 0.4 μv.

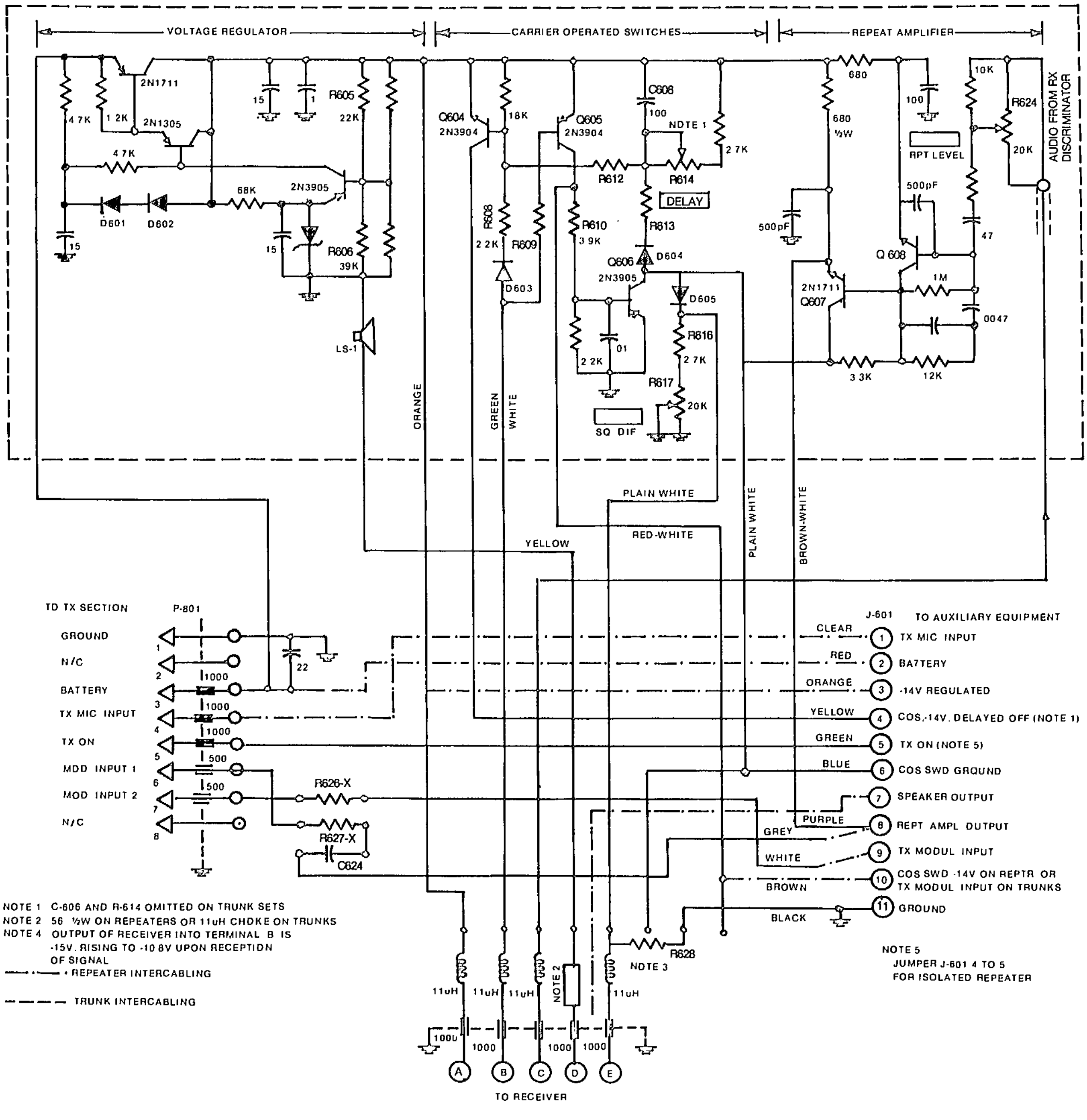


Figure 4. VHF Receiver Control Section

3.3.3.5 Repeat Amplifier

Receiver discriminator output (M-4) is connected to the tie point "C" and repeat level control R-624. Capacitors C-62 in VHF receivers and C-47 in UHF receivers have been removed and the audio signal at M-4 will be pre-emphasized by 6 dB/octave. The repeat amplifier Q-608 and Q-607 will amplify as well as de-emphasize the audio from M-4 for a flat output at pin 8 of J-601. Carrier deviations of plus/minus 3.5 KHz of 1000 Hz audio will produce a level of approximately 0.1 VAC and this is adjusted by R-624 to exactly -8 dBm (0.0887V) at pin 8 of J-601.

The receiver audio stages and the speaker are used for monitoring purposes only, although on repeaters, speaker output is available at pin 7 of J-601 for some accessory applications. The repeat amplifier output at pin 8 of J-601 will be connected to auxiliary equipment via J-601 and in the case of isolated repeaters or trunk drops, it is also connected by an internal jumper to C-624 and R-627 to modulate the transmitter via pin 6 of P-801.

3.3.4 Transmitter Control Section

The transmitter control section is shown in schematic form in Figure 5.

3.3.4.1 Voltage Regulator

Battery supply of minus 15 to 21 VDC is connected to pins 2 and 4 of P-802, and via L-801 to the emitters of Q-811 and Q-804. Switching S-801 to the "ON" position will turn on Q-804, providing battery supply to transistors Q-805 to Q-809. Q-805 will normally be turned on via D-801, R-816 and R-817, thereby turning on Q-810 via R-835. Q-810 will start to turn on Q-811 until the voltage at the collector of Q-811 reaches 14V. At this point, CR-803 and D-808 to D-811 will start to conduct, establishing an additional current through R-833 and creating a bias at the emitter of Q-810.

Since the voltage at the base of Q-810 is held constant by D-804 and D-805, conduction of Q-810 and thereby Q-811 will be limited, establishing a regulator output of 14V. The "Operate-Tune" switch S-802 is used to short D-809, D-810 and D-811 to establish a lower regulation threshold to facilitate operation or tuning of the transmitter at a reduced supply of 12V.

3.3.4.2 Metering

The regulator output is connected via the 0-500 MA meter M-801 to tie point "G", which supplies all transmitter circuits with the exception of the final power output stage in the case of 5W VHF models. On these models only, a 0—1 mA meter (M-802) and a battery test button (S-803) is provided. With S-803 in the normal position, M-802 is connected across L-813, which is trimmed to act as a meter shunt, converting M-802 to read 0—1000 mA full scale and monitoring the current to tie point "H" which supplies the 5W stage only.

Depressing S-803 will remove M-802 from this circuit and connect it across the battery supply via R-831 and R-832. In this condition, M-802 will indicate the battery supply voltage if the reading taken on the 0—1 scale is multiplied by 20 (0—20V full scale).

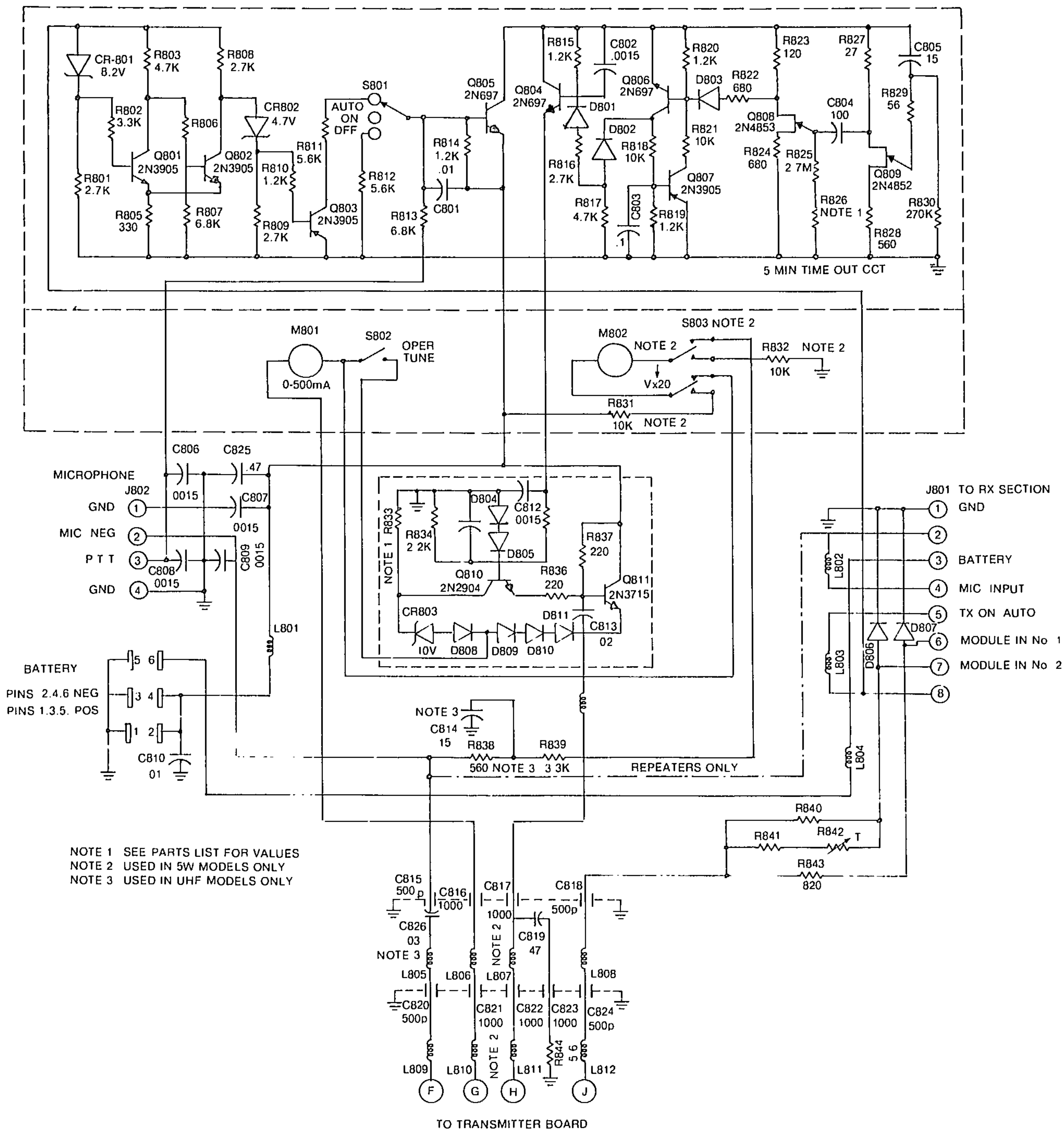
3.3.4.3 Automatic Transmitter Control

Transmitter control voltage is connected from pin 5 of J-601 to CR-801 via pin 5 of J-801 and L-803. This voltage can either be supplied by auxiliary equipment connected to J-601 or, in the case of isolated repeaters or trunk drops, from the carrier operated switch Q-604 and a jumper from 4 to 5 of J-601.

Transistors Q-801 and Q-802 form a Schmitt trigger circuit to provide fast switching of Q-803. Zener diode CR-801 establishes a minimum control voltage requirement of approximately 11V to turn the transmitter on. This will prevent transmissions from abnormally low battery supply and will ensure sharp transmitter turn off from a decaying control voltage (see TX off delay).

3.3.4.4 Five Minute Timer

Whenever Q-804 is switched on, battery voltage is supplied to Q-806, Q-807, Q-808 and Q-809. Transistors Q-806 and Q-807 originally remain in the off condition, enabling Q-805 to turn on the regulator and transmitter. Momentarily disregarding Q-809, capacitor C-804 will charge slowly at a rate determined by R-825 and R-826. After several minutes the charge on C-804 will reach the peak point of Q-808 and Q-808 will conduct and discharge C-804. This produces a pulse across R-823 and to the base of Q-806. Q-806 will be



TRANSMITTER CONTROL SECTION 'BR' SERIES REPEATERS

Figure 5. VHF Transmitter Control Section

turned on and will latch up with Q-807. With Q-806 in conduction, Q-805 and thereby the transmitter, will be disabled. This condition will remain until Q-804 is momentarily turned off, breaking the latch between Q-806 and Q-807. If Q-804 is momentarily turned off before C-804 has reached the peak point of Q-808, capacitor C-804 will quickly discharge via the emitter of Q-808 and the timer will be reset to the full cycle. The circuit of Q-809 is added to ensure reliable operation of Q-808 by overcoming the problems of leakage of C-804 and peak point current requirements of Q-808. Q-809 will periodically send a positive pulse across R-827 and the negative side of C-804 thereby momentarily raising the positive potential of C-804 and ensuring reliable firing of Q-808 whenever the combination of the charge of C-804 plus the pulse across R-827 exceeds the peak point of Q-808.

3.3.4.5 Modulator Inputs

A microphone socket (J-802) is provided for local use of the repeater transmitter. The output of the microphone is connected to tie point "F" which is connected to the junction of R-120 and C-145 in VHF transmitters, and to the base of Q-8 in UHF transmitters. In either case, the microphone output is passed through the standard clipper and integration circuits of the transmitter, limiting maximum deviation to 5 KHz. In the case of UHF sets only, R-838, R-839 and C-814 are installed to provide the required microphone DC supply.

3.3.5 R.F. Electronics' BR-39 Control Panel and DTMF Decoder

Figure 6 is a schematic diagram of the BRA-39 control panel. The panel is connected to sockets J-601 of the VHF set (triangles) and the UHF set (squares). The voltage regulator Q-1 uses a -14V reference from the repeater (triangle 3) to supply -13.2V regulated to the panel.

A Baron Communications TTD-19 DTMF decoder is used to establish the connection of the repeater to the UHF link. The decoder is wired for the single digit * (star) and C-41 has been increased to 15 μfd to prevent false output with single digit operation.

The decoder is turned on by Q-2 which is controlled by the VHF COS.

Decoder output will set the latch of Q5 and Q6.

With the latch set, Q-9 will be enabled and UHF COS at square 4 will turn on the VHF transmitter at triangle 5. The latch will also enable Q-4 and VHF COS switched ground at triangle 6 will turn on the UHF transmitter at square 5 via Q4 and Q3.

The latch will also enable the 2 second timer Q8. However, as long as there is COS output from either the VHF or the UHF receiver, the timer will be disabled by D7 and D8. In the absence of COS from either receiver for a continuous 2 seconds Q8 will fire turning on Q7 and resetting the latch.

3.3.6 UHF Transceiver

The UHF transceiver consists of a Motorola type NRE 1001 receiver and an NTE 6001 transmitter. These units together with additional control circuitry have been integrated by R.F. Electronics Ltd., Vancouver, and marketed as type BR-150-.7 repeater systems. The interface circuitry which connects the VHF and UHF transceivers together is described in Sections 3.3.3, 3.3.4 and 3.3.5 of this report.

3.3.7 Antennas

The UHF transmitter and receiver both use a Sinclair type SRL-307 seven element yagi antenna having a gain of 10 dB and a front to back ratio of 15 dB. The input impedance is 50 ohms.

The VHF antenna is a Sinclair Model 228B Collinear whip (gain 6 dBd) giving a vertically polarized omni-directional radiation pattern.

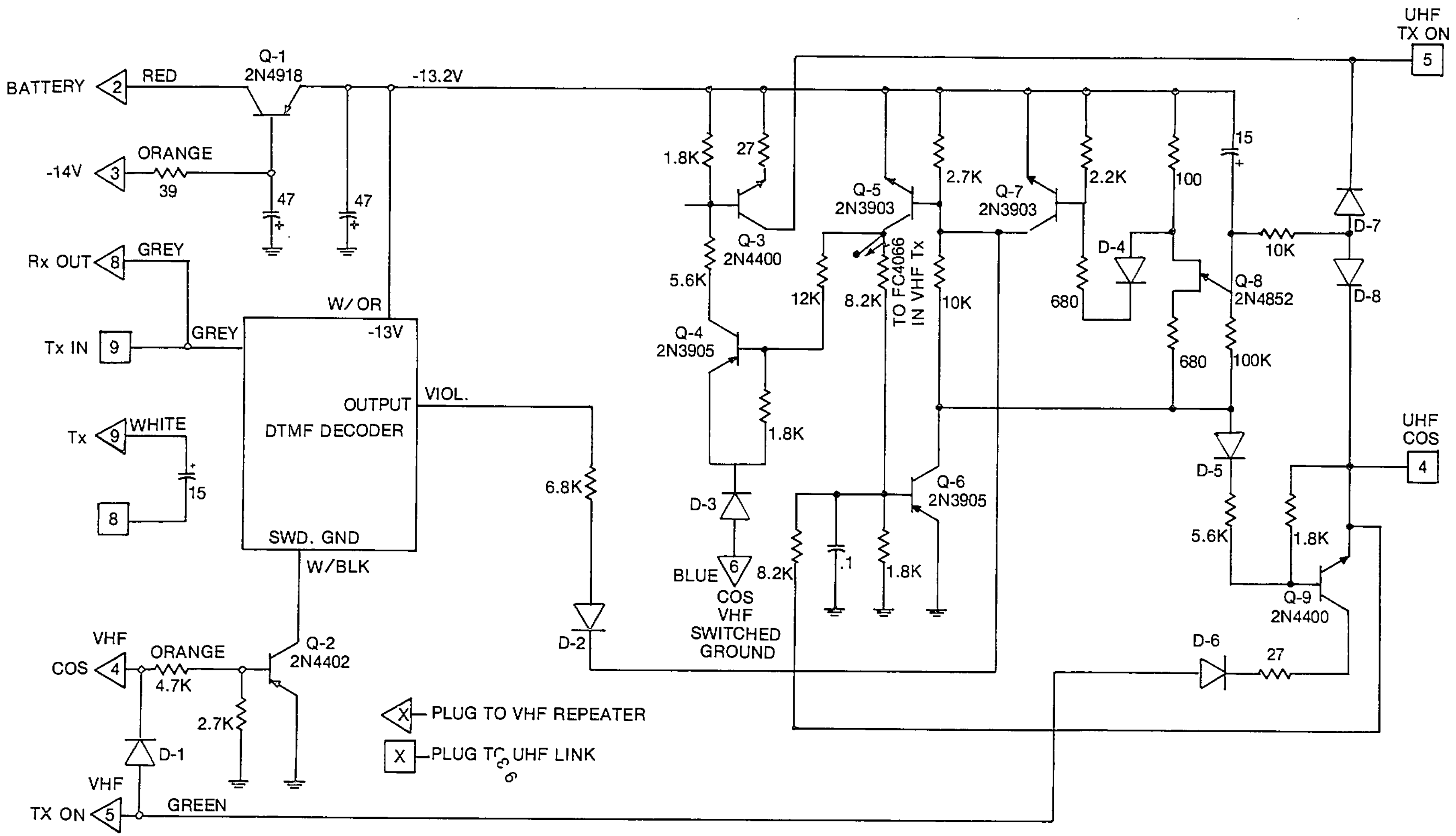


Figure 6. BRA-39 Control Panel

3.4 BASE STATION EQUIPMENT

3.4.1 UHF Antenna

The base station antenna is a Sinclair type SRL-307 yagi identical to the UHF mountain-top antenna described in Section 3.3.7 of this report.

3.4.2 UHF Transceiver

The base station transceiver is identical to the unit described in Section 3.4.2 of this report. Its interface unit is different however and it is described in Section 3.4.3.

3.4.3 R.F. Electronics' BRA-41 Interface Panel and Data Signals' RAP 400 Autopatch

The R.F. Electronics' BRA-41 interface panel in its original form comprised a transmitting compression amplifier, an audio amplifier to provide the correct signal level for injection into the telephone line, an autopatch control providing automatic connect, disconnect and transmitter keying function and a tone decoder.

The off-hook relay and telephone coupling transformer were eliminated and replaced by a Data Signal Corp. type RAP-400 autopatch unit which, by providing additional sophistication enabled signal validation and signal inhibit (prevention of long-distance dialing) in addition to the connect-disconnect function. The circuit diagram of the modified unit is shown in Figure 7. In this diagram, and others designed by R.F. Electronics, interconnect terminals are numerically marked. Squares refer to UHF inputs, and triangles refer to VHF inputs.

Upon receipt of the correct access code, the UHF hilltop transmitter is turned on. The carrier, when received at the base station site causes the input signal at terminal "square 4" to change from ground to minus 14V. Relay E1 closes enabling the base station transmitter. Simultaneously, the latch Q4, Q5 is set locking the base station transmitter "on". Control signals and touch-tones transmitted via the UHF link enter the RAP-400 autopatch unit via audio amplifier IC3. Signals from the telephone line modulate the UHF base station transmitter via compression amplifier IC1, IC2.

Upon receipt of the correct disconnect code, the TTD-19 decoder delivers an output pulse to transistor Q3. This opens the latch Q4-Q5 and disconnects the UHF link by turning the base station transmitter off.

4. AN HF/SSB RADIO TELEPHONE INTERCONNECT SYSTEM

As already mentioned, a selective call system for use with SSB (suppressed carrier) systems must employ special techniques to provide reliable operation in the presence of noise and interference and voice in the channel, with frequency differences of tens even hundreds of hertz between the transmit frequency and the local oscillator at the receiver. This is achieved by sending a pair of tones (DTMF) for each digit to be transmitted, but employing at the receiver compression amplifiers, and filters to select the difference frequency between the reference and information tones. These difference frequencies remain relatively constant when the frequency shifts and permit a frequency tolerance of ±500 Hz in SSB systems. Thus, the selective call will operate reliably with trail and remote camp radio transceivers that may be considerably "off-frequency" due to the rugged environment (cold and vibration) that the portable radios are subject to.

The most difficult part of the system designed turned out to be the transmit/receive switch at the HF base station, since a carrier-operated switch (COS), which for VHF—FM transmission provides reliable switching down to levels near to signal threshold, cannot be employed.

The initial idea was to give control of the switching to the called telephone party, after the initial functions of access, and dialing had been completed. Thus, when the called telephone party picked up his

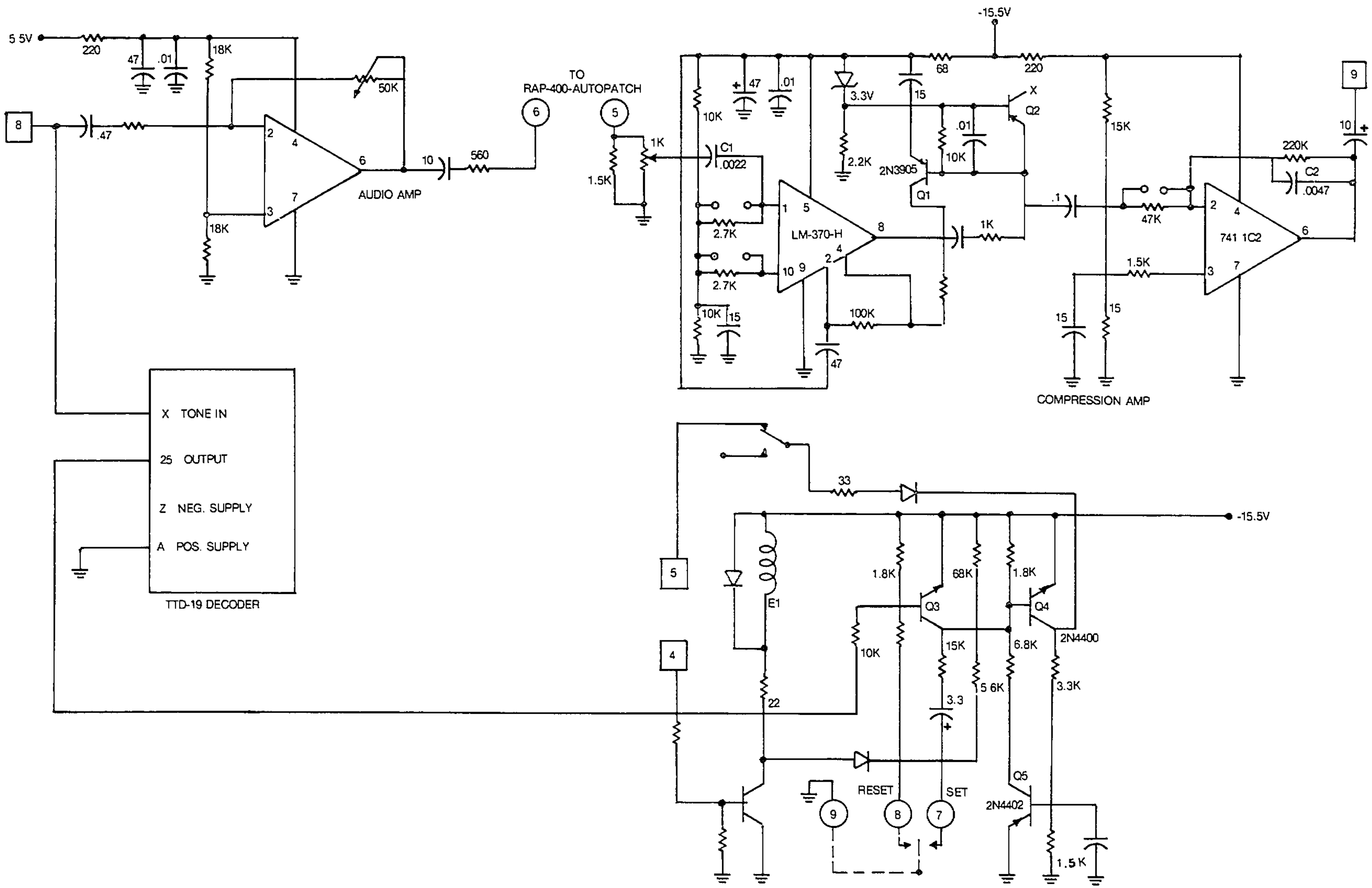


Figure 7. BRA-41 Control Panel

phone, his voice would activate a voice-operated transmit (VOX) switch. However, the telephone patch hybrid transformer and its balancing network, when connected to actual telephone lines, provided only 10–20 dB isolation between the received radio signal and the speech of the called telephone party, and since automatic gain control (AGC) had to be used to hold levels constant, this degree of isolation was insufficient. Noise and interference received by the HF-SSB base station receiver actuated the VOX control which, of course, made the system malfunction.

The system finally adopted utilized dual control, that is, VOX operation on the speech of the called telephone party is still employed, but when the mobile operator uses the autopatch, he presses his microphone button and a 250 ms DTMF tone burst is sent over the link which closes a switching relay, and when he finishes speaking, and lets his microphone button go, another DTMF tone burst is sent over the link to open the relay. These beeps will likely not be annoying to the user, in fact, the user could come to like to hear them since the second beep indicates that it is the called party's turn to talk.

The various signaling frequencies on the telephone line provide the initial control (see Figure 8). The mobile operator dials * to "access" the system. If this is properly received, the off-hook flip/flop closes the off-hook relay in the voice station coupler (a unit supplied by the telephone company). The dial tone detect circuitry detects the dial tone, and turns on the HF transmitter briefly, allowing the mobile operator to hear the dial tone when he releases his microphone button. When the base station transmitter is silent, the mobile operator presses his microphone button again and touches out the telephone number he wishes to call. He lets go of his microphone button. Dependent on the telephone exchange, the regenerated AT&T touch-tones (TM) can be used to dial directly, or these digits are converted to binary code, and entered into a first-in-first-out (FIFO) memory, and sequentially dialed out by a dial pulse converter. If a successful dialing operation has been achieved, a ringing signal appears on the line. If a busy signal is detected, the system hangs itself up automatically. Each ringing signal turns on the HF base station transmitter so that the mobile operator can hear the phone ringing. If after 10 rings, there is no answer the RTI control hangs up the phone automatically and reverts the system to standby. If the called party answers, the voice-operated transmit control (VOX) turns on the transmitter and the mobile operator hears him speaking. Operation continues as described above, and when complete, the mobile sends the digit # which hangs up the phone. If propagation conditions change before he hangs up the phone and he is unable to do so, the dial tone which appears on the line 30 seconds after the called party has hung up is detected and used to perform the automatic hang-up and reset to standby operation. The digit # in addition to initiating the manual hang up operation also resets all the counters and gates in the transmitter control unit. This digit is therefore included at the beginning of each transmission to ensure that the timing sequences proceed in the correct order.

4.1 GENERAL SYSTEM DESCRIPTION

The block diagram, Figure 8 shows the complete system configuration. The portable transceiver can be modulated with various dual-tone combinations selected by either a keyboard to encode connect, disconnect and dialing functions, or by the microphone PTT switch for switching functions. The microphone unit in addition to controlling the switching tones also provides voice modulation in the normal way.

When the dialing or control tones are received at the base station, they are decoded and used to regenerate standard touch-tones. The touch-tones are utilized in (a) an autopatch unit which controls connect-disconnect-inhibit operations, and (b) a dial pulse converter which generates dial pulses from the regenerated touch-tones. If a touch-tone line is available, the dial pulse converter is not necessary.

A transmitter control unit monitors signals from the telephone line and automatically controls the transmission of dial tone, busy signal, ringing signal or voice received from the line. Automatic "hang-up" under several possible conditions is also provided for.

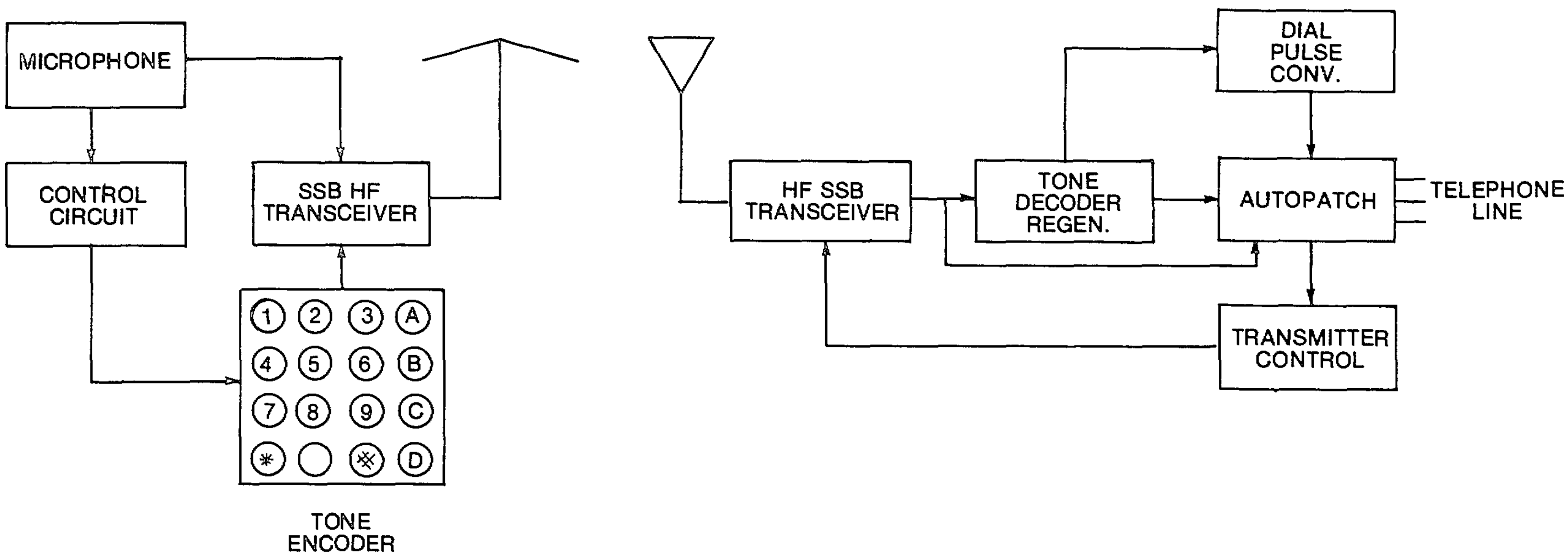


Figure 8. HF/SSB Radio-Telephone Interconnect System — Block Diagram

4.2 PORTABLE EQUIPMENT

4.2.1 HF SSB Transceiver

The transceiver used as a portable unit was a modified Spilsbury Communications' type SBX-11A.

The battery compartment was slightly enlarged to house a Gates 4AH sealed lead-acid cell. The microphone preamplifier circuit was modified to receive input signals from the tone encoder. The circuit diagram is given in Figure 9.

4.2.2 Tone Encoder

The tone encoder is a Baron Communications type* ME-0801 modified to enable the letters D and B to be encoded respectively each time the microphone push to talk switch is closed and opened. These two letters control a relay in the autopatch unit enabling the connection of the telephone line to either the base station transmitter or receiver. The encoder consists of a keyboard (Figure 10), a pilot tone generator (Figure 11), an information tone generator (Figure 12) and a combiner/PTT circuit (Figure 13).

The pilot tone generator level is 6 dB higher than that of the information tone generator.

Each time a letter or digit is transmitted, the SBX-11A PTT relay is energized. A holding circuit prevents the relay from opening between consecutive digits.

4.2.3 Control Circuit

Automatic encoding of the letters B and D used for telephone line switching is accomplished by the control circuit shown in Figure 14. When the microphone PTT switch S1 is closed, relay E1 closes causing C1 to discharge thereby triggering the timer IC1 . The timer IC1 generates a positive 5 volt pulse 250 milliseconds in duration which closes the relays E2 and E3. Relay E2 applies power to both the pilot tone and information tone PC boards in the ME-0801 encoder. Relay E3 enables the information tone oscillator associated with the letter D. The second section of the microphone switch, S2 energizes the SBX-11A transceiver PTT relay. The result is a 250 millisecond tone burst at the beginning of each transmission.

When the microphone PTT switch is released, relay E1 opens, C4 discharges triggering timer IC2. The positive 5 volt pulse from IC2 turns on transistor Q1 which holds the PTT relay in the SBX-11A set closed. In addition, relays E4 and E5 are energized thereby generating the tones associated with the letter **B**. The result is a 250 millisecond tone burst at the end of each transmission.

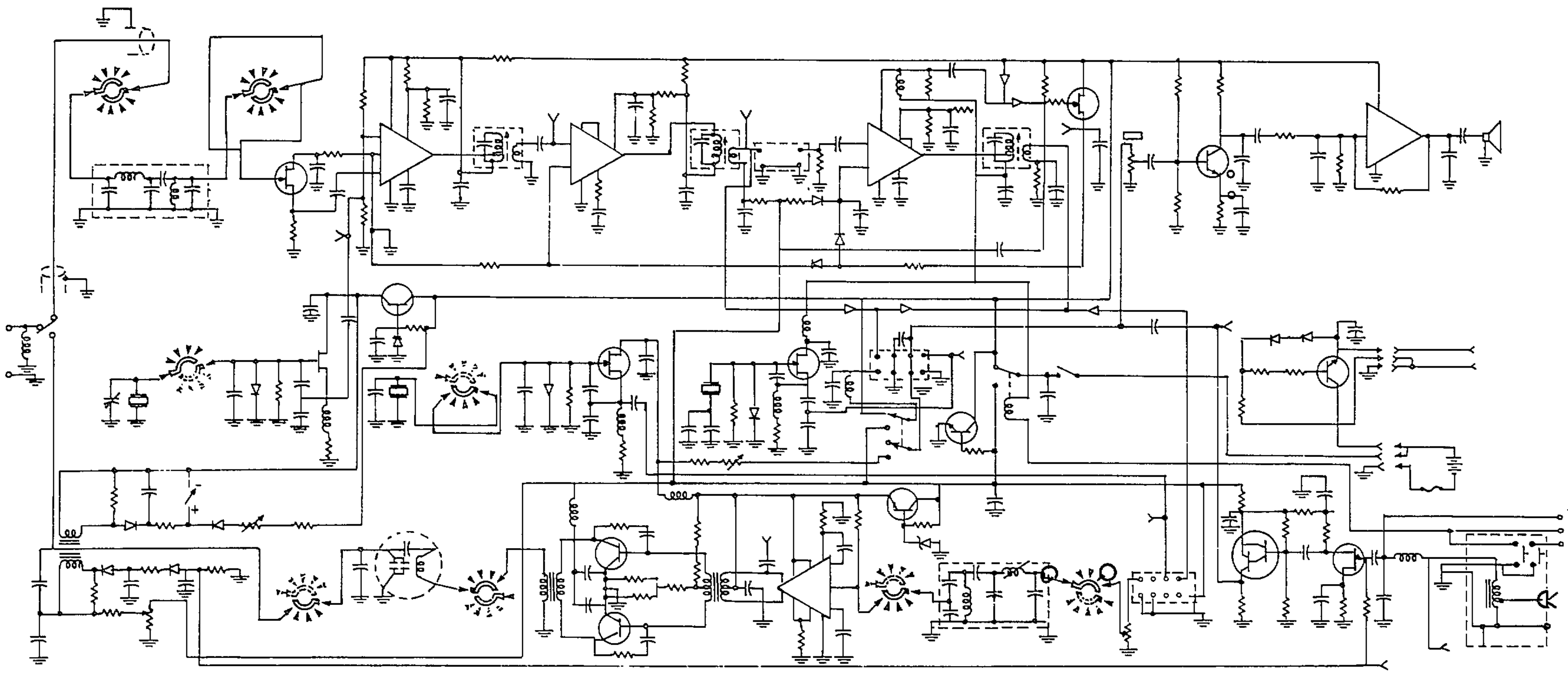
4.2.4 HF Portable Antenna

An inverted V type of antenna is used as the radiating element. During transit, the antenna is wound up on two nylon bobbins which serve as the end insulators when the antenna is in operational use.

Fibreglass tape is used to mark the length of wire to be unwound for use on the selected channel. There are three markers; each corresponds to one of the four available SBX-11A channels. The antenna is full length at the lowest channel frequency.

A 1:1 balun is used to provide balanced-to-unbalanced impedance transformation between the antenna and the 20 ft of coaxial transmission line. The transmission line impedance is 50 ohms.

The antenna is supported at its mid-point by a sectionalized aluminum A-frame. Each leg of the A-frame contains 2 six foot lengths of 1 inch diameter aluminum tubing with a wall thickness of .065 inches. The sections fit together to elevate the antenna approximately 12 feet above the ground. The top sections fit into an aluminum plate fitted with a hook which supports the balun transformer. The bottom leg sections are pointed so that they may be pushed into the ground or snow.



1. ENCODER AUDIO OUTPUT
2. MIC. PTT SW. No. 2 TO ENCODER CONTROL Q1
3. MIC. PTT SW. No 1 TO
   ENCODER CONTROL E1, PIN 6

Figure 9. Schematic Diagram Modified SBX-11A Receiver

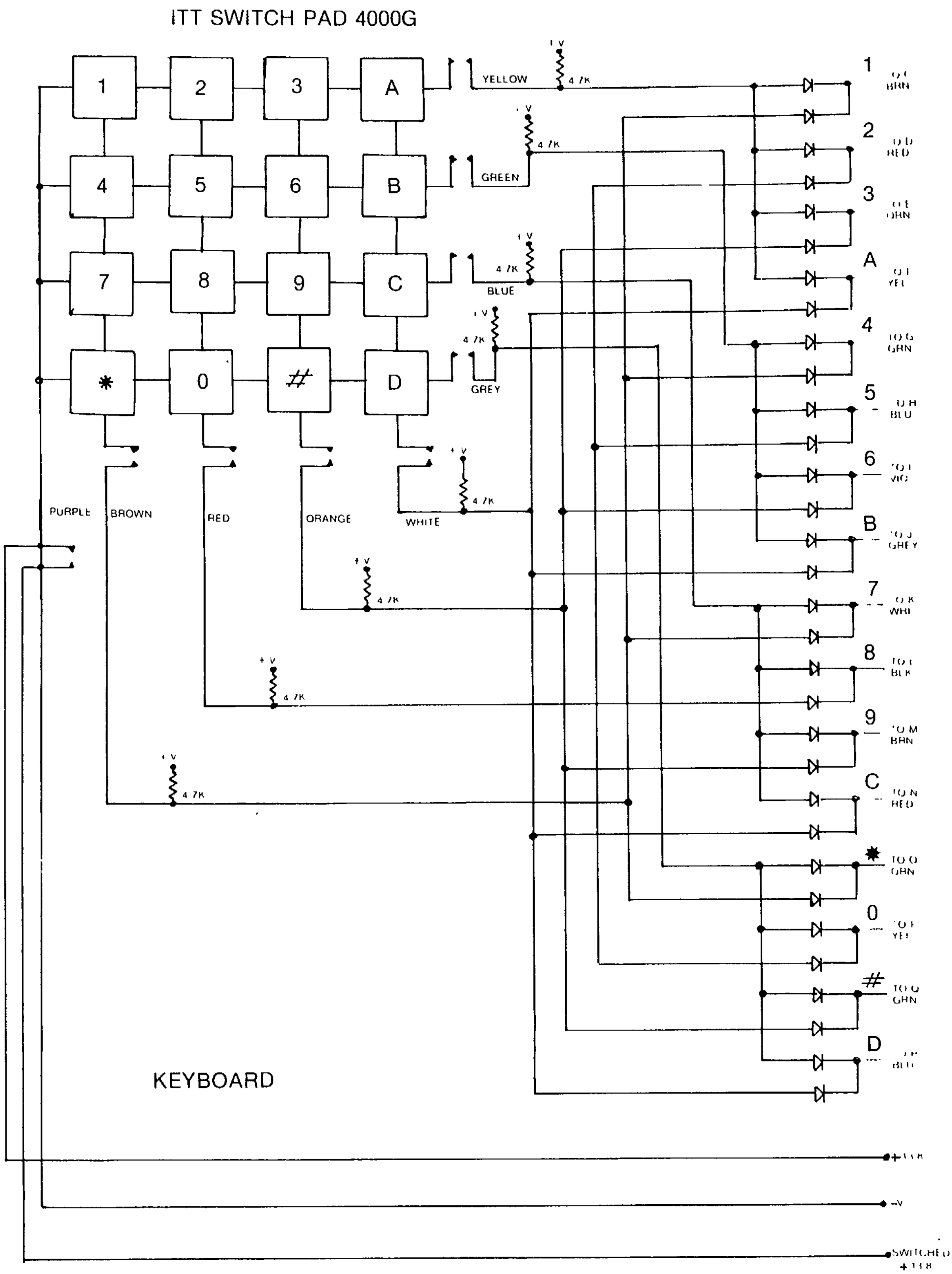


Figure 10. ME-0801 Encoder Keyboard

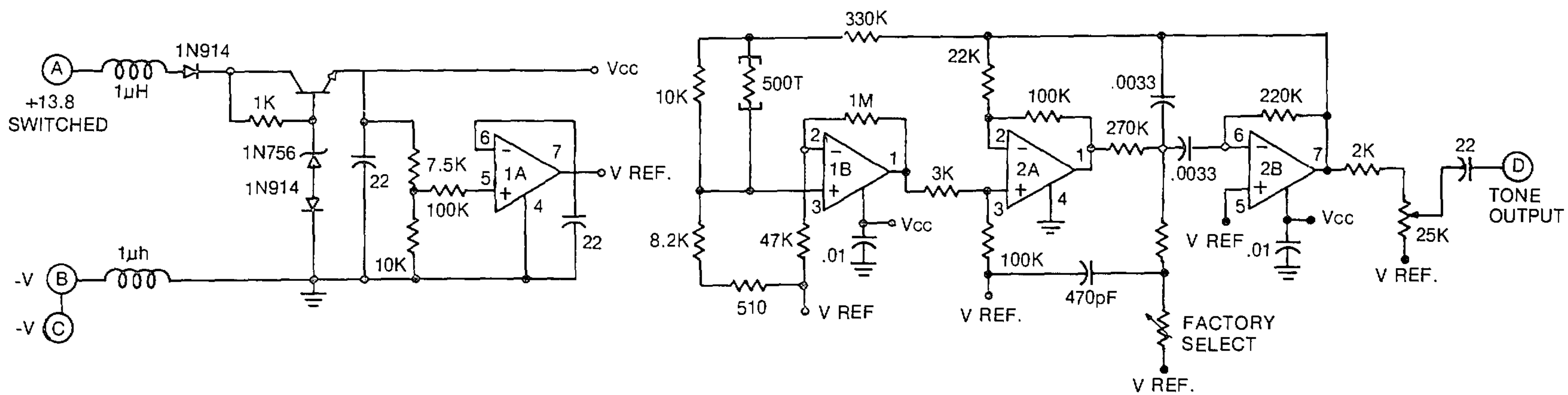


Figure 11. ME-0801 Encoder Pilot Tone Generator

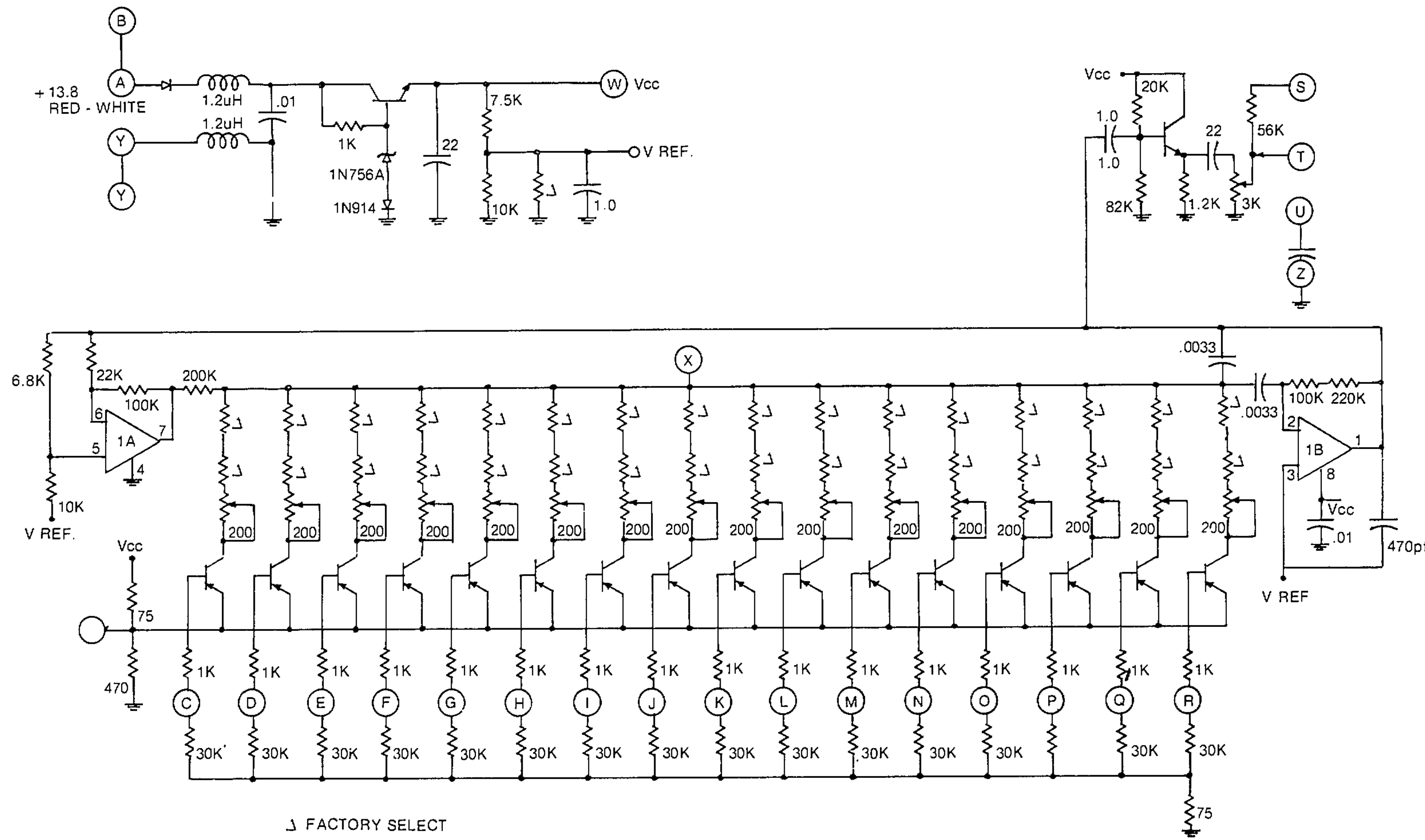
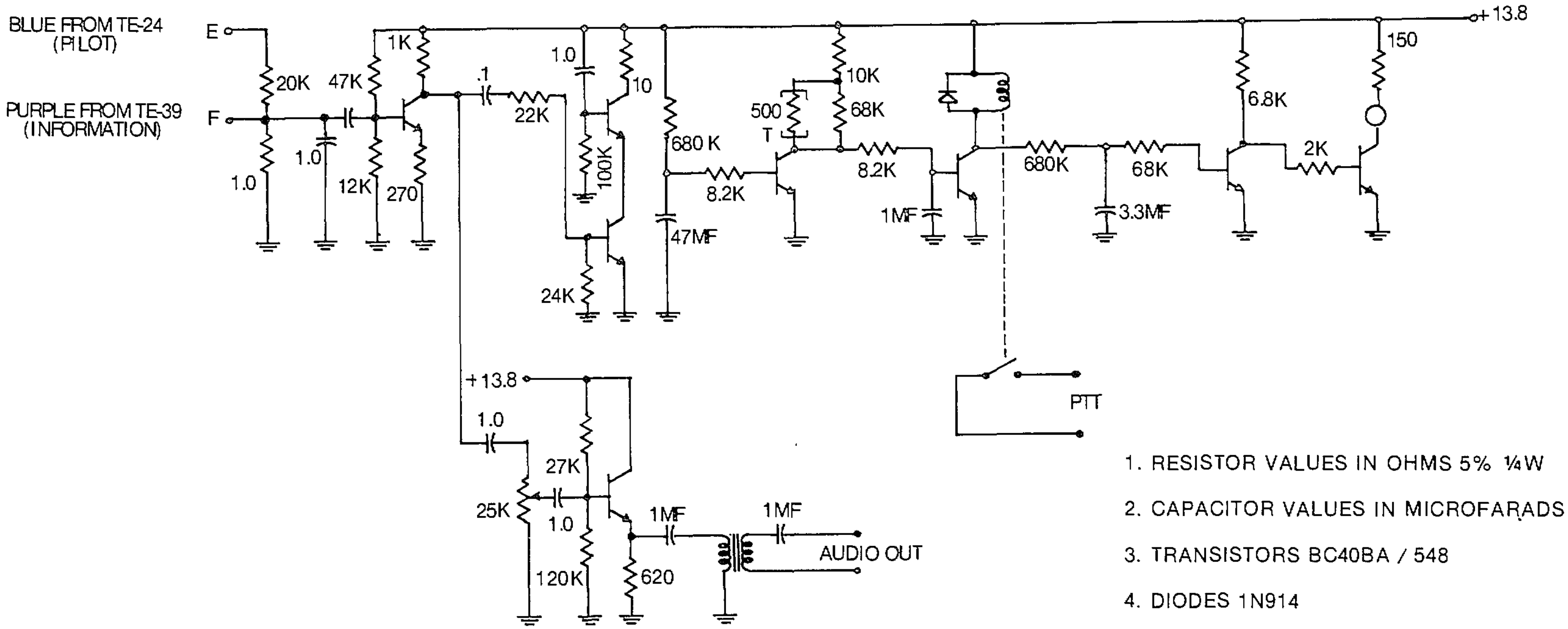


Figure 12. ME-0801 Information Tone Generator



TTE-10

Figure 13. ME-0801 Combiner/PTT Circuit

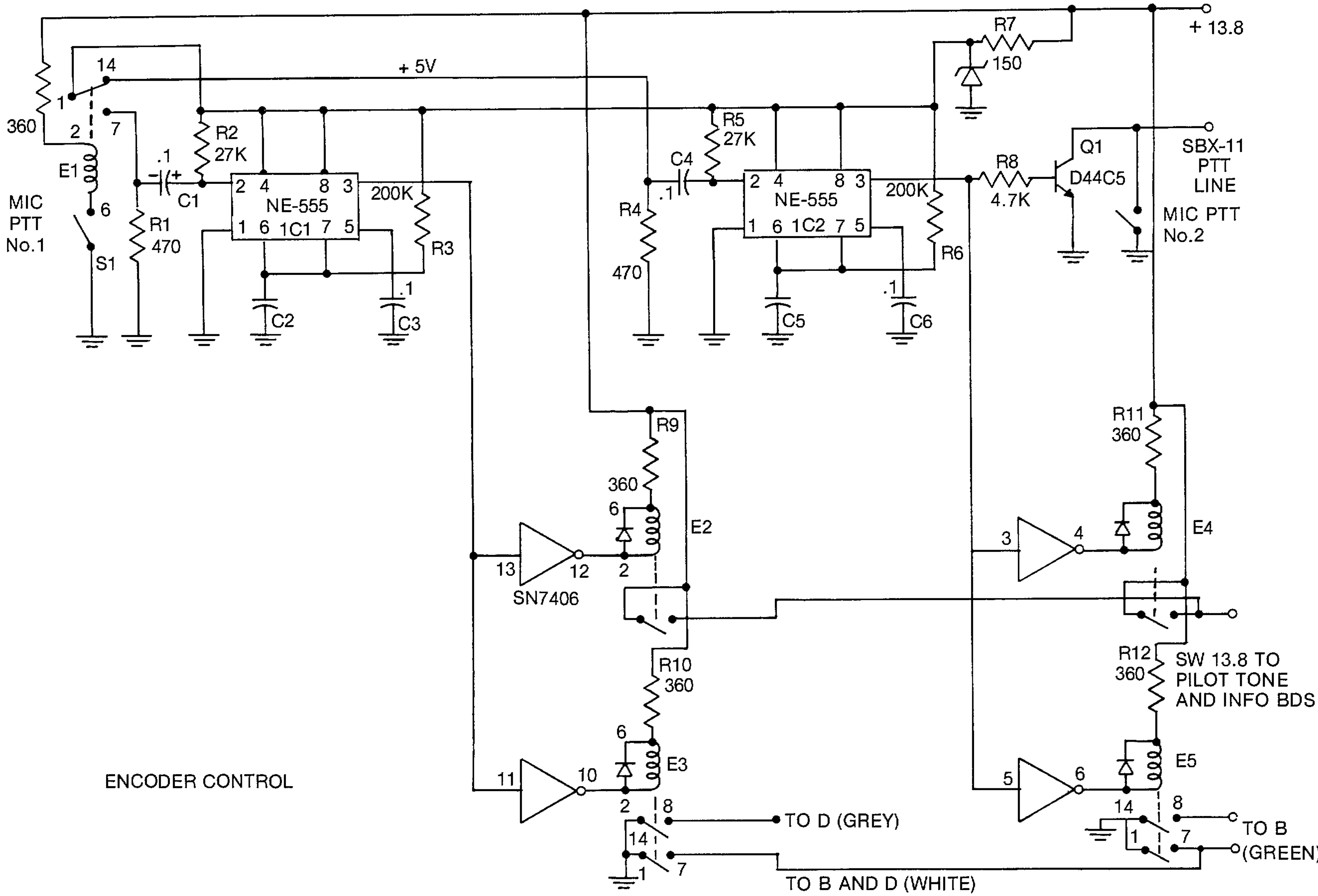


Figure 14. SBX-11A Encoder Control Unit

Each of the nylon bobbins contains 30 feet of nylon cord which can be extended to anchor the antenna ends to either pegs or a heavy rock.

The length of wire to be used for a given channel was determined with a forward-reflected power meter inserted in the coaxial antenna feed line when the antenna was erected to its maximum height. The length was adjusted symmetrically about centre until the reflected power on transmit was zero. This length was marked by fibreglass tape as noted above.

The antenna wire, bobbins, balun, pegs, coaxial cable, the aluminum top-plate and the leg sections are conventiently carried in a canvas bag specially designed for the purpose.*

4.3 BASE STATION EQUIPMENT

4.3.1 CH-100 Transceiver

A Marconi CH-100 transceiver which was used at the base station was modified to permit direct electrical connection of its modulator and receiver audio sections to the autopatch and transmitter control units.

4.3.2 Tone Decoder Regenerator

The tone decoder-regenerator is a Baron Communications Corp. type BD-0802. It consists of a type TF-1 tone filter, two TTD-15 decoders and a type TTE-10 DTMF encoder.

The TF-1 tone filter is shown in Figure 15. The output of the base station SSB receiver is applied to a buffer amplifier Q6 for impedance matching prior to the compression amplifier IC1 Q-1. The audio signal is then applied to a high-pass filter with a passband of 1100–2400 Hz. This removes all products of mixing leaving only the pilot tone and information tones. The second compression amplifier IC2-Q3 assures a constant amplitude input to the envelope detector Q4. The resultant signal which contains the original tones and their sum and difference frequencies is applied to a low-pass filter L2, L3, L4, C-19. This filter removes the original frequencies and the sum frequency leaving the stable difference frequency to be amplified by the final compression amplifier IC3, Q5.

The difference frequencies are next applied to the two TTD-15 boards (Figures 16, 17). Each TTD-15 board contains 8 narrow band filters each centred on one of the difference frequencies enumerated (see Table 1). Each of the filters has a dual diode coupled output which is fed to the TTE-10 encoder board. Figure 18 shows the schematic diagram of the TTE-10 board. IC2 is a DTMF oscillator requiring one high band and one low band input signal to generate a dual-tone output. The dual output signals from the TTD-15 boards are coupled to the appropriate oscillator inputs via the transistor switching array IC1.

The transistors Q11, Q9 amplify the dual-tone signal. Transistors Q6, Q10, Q7 and Q8 further amplify and rectify the audio tones to drive a PTT relay. The PTT relay is not used in this case.

4.3.3 Dial Pulse Converter

If a touch-tone telephone line is not available, the regenerated DTMF tones have to be converted to dial pulses. This was accomplished by a Model DPC-21 Dial Pulse Converter manufactured by Data Signal Inc. The circuit diagram is shown in Figure 19.

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* *A commercial copy of this antenna is available from Spilsbury Communications Systems, Vancouver, B.C.*

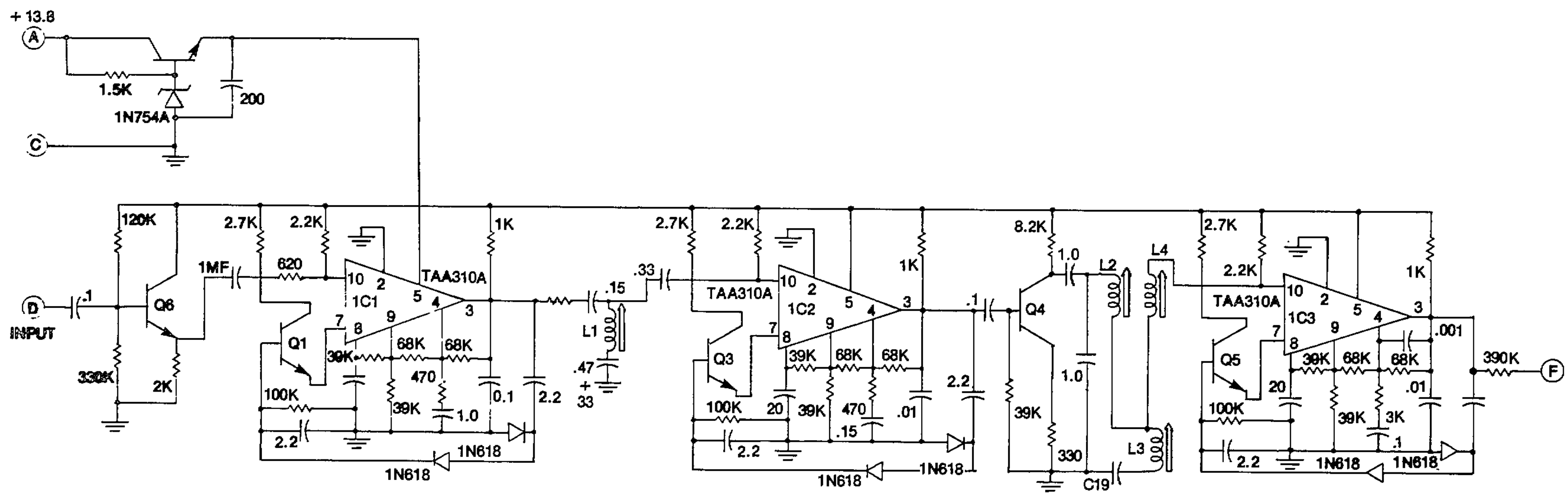


Figure 15. BD-0802 Decoder Tone Filter Type TF-1

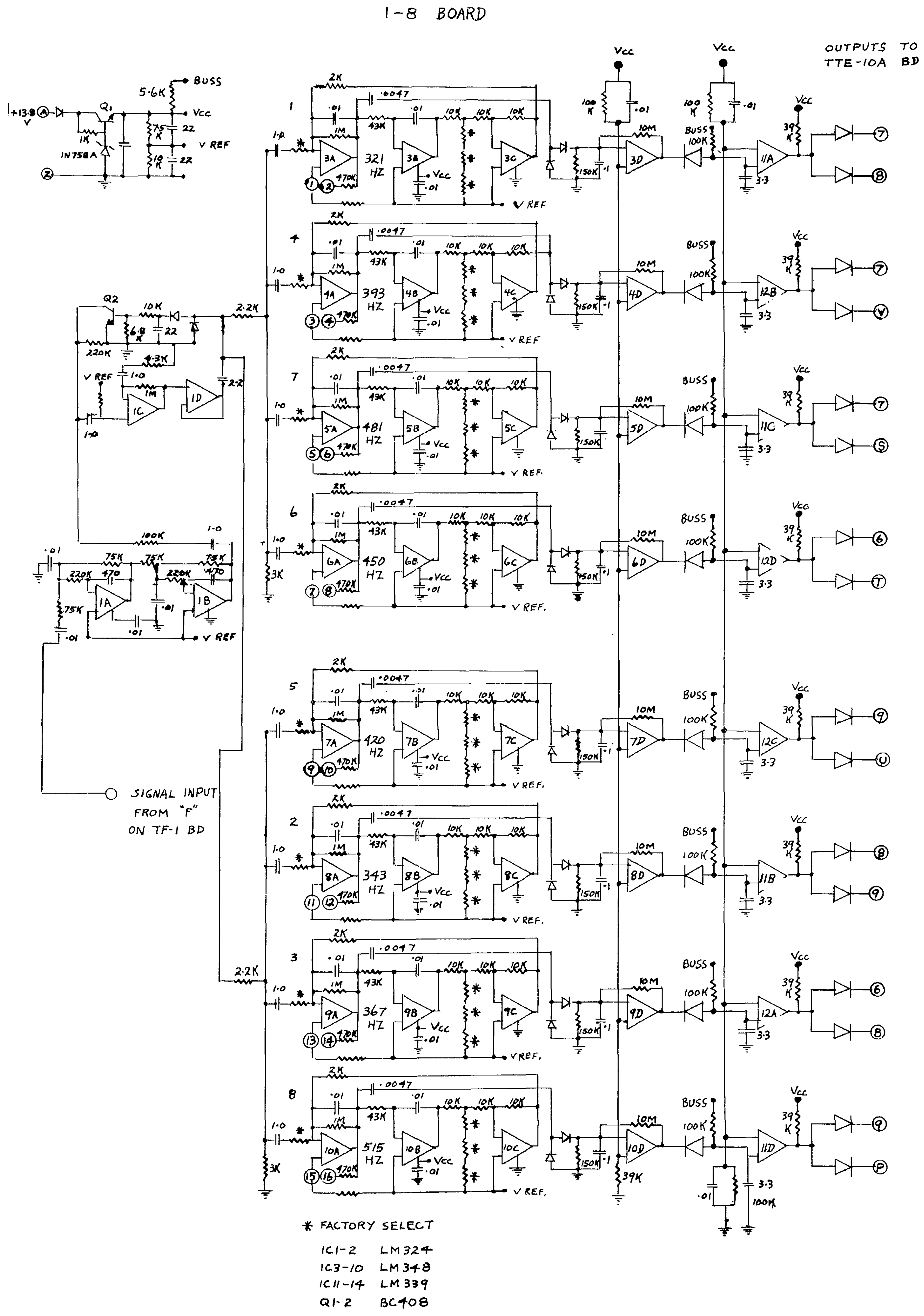
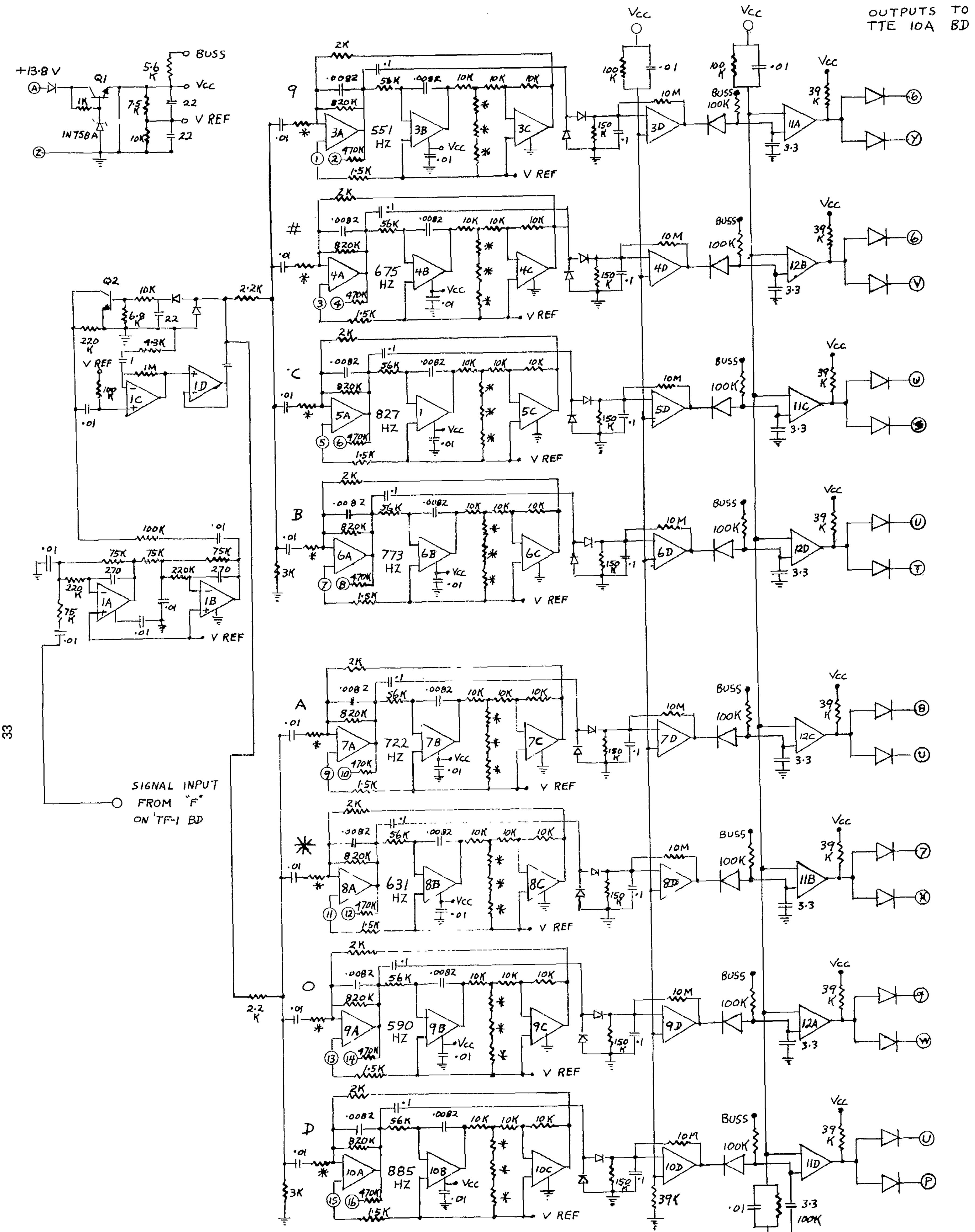


Figure 16. BD-0802 Decoder Type TTD-15 1-8

TTD 15 BOARD

9-D BOARD



✱ FACTORY SELECT

IC1-2 LM324

IC3-10 LM348

IC11-14 LM339

Q1-2 BC-408

TTD 15 BOARD

Figure 17. BD-0802 Decoder Type TTD-15 9-D

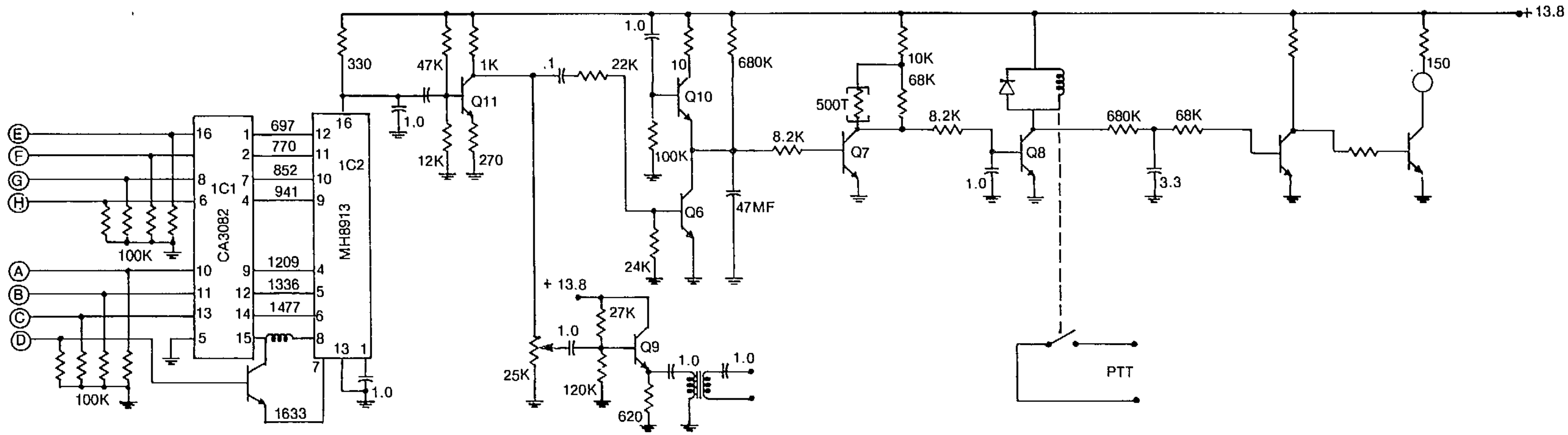


Figure 18. TTE-10 Encoder Board

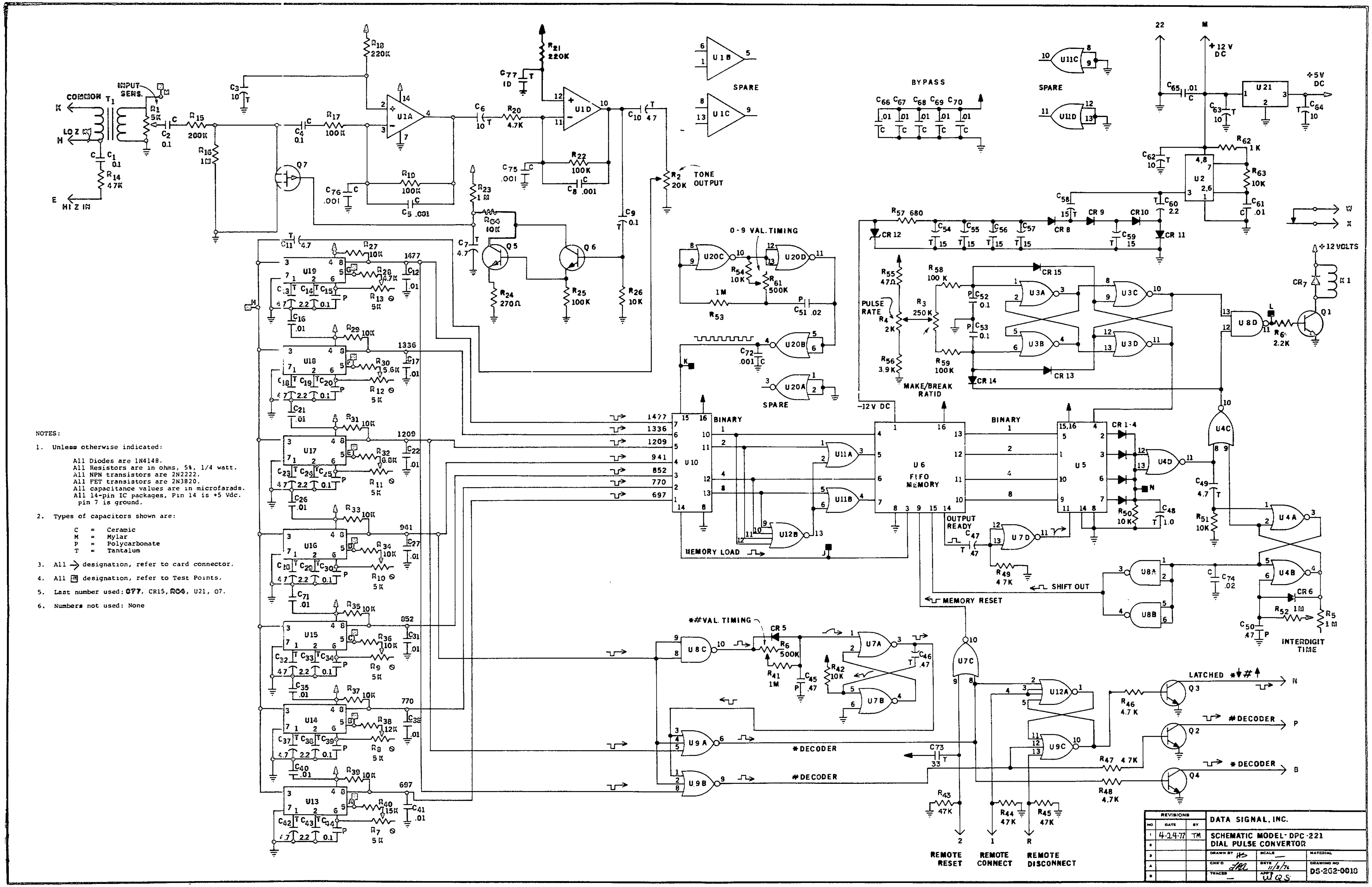


Figure 19. Dial Pulse Converter, Data Signal Corp. Type DPC221

4.3.4 Autopatch

The autopatch unit is a modified Data Signal Corp. Model RAP-400 shown in Figure 20.

The regenerated touch-tones from the BD-0802 decoder regenerator are applied to a bank of type NE-567 phase locked loop tone decoders. Each decoder is tuned to a different frequency as shown in Figure 20. The output of each decoder, pin 8 is normally high and will go low when a tone is decoded. To ensure against false decoding of noise or extraneous signals, a validation timer U12 is used. When an incoming digit is being decoded one or more cathodes of diodes D2—D6 will be low preventing Q1 from conducting. Whenever Q1 releases the clamp across C1, it is allowed to charge thereby starting the validation timing which is set to 250 milliseconds. If, at any time during the validation process, the clamp is re-applied C1 will be discharged. The instant validation occurs pin 3 of U12 goes to a low. IC's U9, U10, U11 perform logic operations associated with the connect, disconnect and inhibit functions in conjunction with switches S-3, 4, 5, 6. By appropriate switch settings, the autopatch will, if desired, disconnect if the first digit dialed is a 0, 1, 8 or 9.

U8C and U8D form an R—S flip-flop which drives the on-off hook relay E1. The encoded signal * produces "off-hook" condition. The encoded signal # causes the disconnect or "hang-up" condition. U13A and U13B form an R—S flip-flop which controls a clamping transistor across the primary winding of T4, thereby preventing audio signals from being injected into the phone system until the dialing process has been completed. The cycling time has been set at 20 seconds.

U14A and B together with transistors Q8, 9, 10 form an AGC amplifier which keeps signals received from the telephone line at a constant level for injection into the transmitter modulator and the transmitter control unit.

U14C and D together with transistors Q2, 3, 4 form a second AGC amplifier which stabilizes signals from the base station receiver at a constant level prior to injection into the telephone system.

U18A and B are coincidence detectors which detect the presence respectively of the tones associated with the letters B and D together with the validation signal. Upon receipt of the encoded letter D, flip-flop U17A—B is set causing pin 3 to go high. This causes relay E2 to close thereby switching the telephone line to the output of the receive AGC amplifier so that signals from the portable unit may be directed to the called party. Upon cessation of voice transmission, the portable unit transmits the encoded letter B which resets flip-flop U17A—B, opening relay E2 and connecting the telephone line to the transmit AGC amplifier. In this way, signals from the telephone line are now transmitted to the portable unit.

4.3.5 Transmitter Control

The response of a telephone network to an "off-hook" condition is a continuous dial tone comprising the frequencies of 350 and 440 Hz. Upon completion of dialing, the dial tone is replaced with either a ringing signal (440 and 480 Hz), or a busy signal (480 and 620 Hz). The ringing signal has a repetitive cadence of 4 seconds on and six seconds off. The busy signal has a duty cycle of 0.5 second on and 0.5 second off. If the call is successful, the various control signals are replaced by the voice signal of the called party.

The transmitter control unit, (Figure 21) contains four separate signal channels. Each channel is preceded by a gate U1A, B, C, D which allows signals to enter when open and prevents signal entry when closed. The channel preceded by U1A responds to the dial tone signal and controls transmission of the dial tone to the portable unit. The channel preceded by U1B responds to a ringing signal. It controls the transmission of the ringing signal to the portable unit and also "hangs-up" if there is no answer. The channel preceded by UIC responds to a busy signal. It controls the transmission of the busy signal to the portable unit and "hangs up" after 10 busy tones. The channel preceded by UID performs two functions. In response to a voice signal, it acts as a VOX control unit for the CH-100 base station transmitter. After "hang-up" by the called party, it monitors the telephone line for the return of the dial tone signal approximately 30 seconds later and then performs line disconnect or "hang-up" of the base station phone.

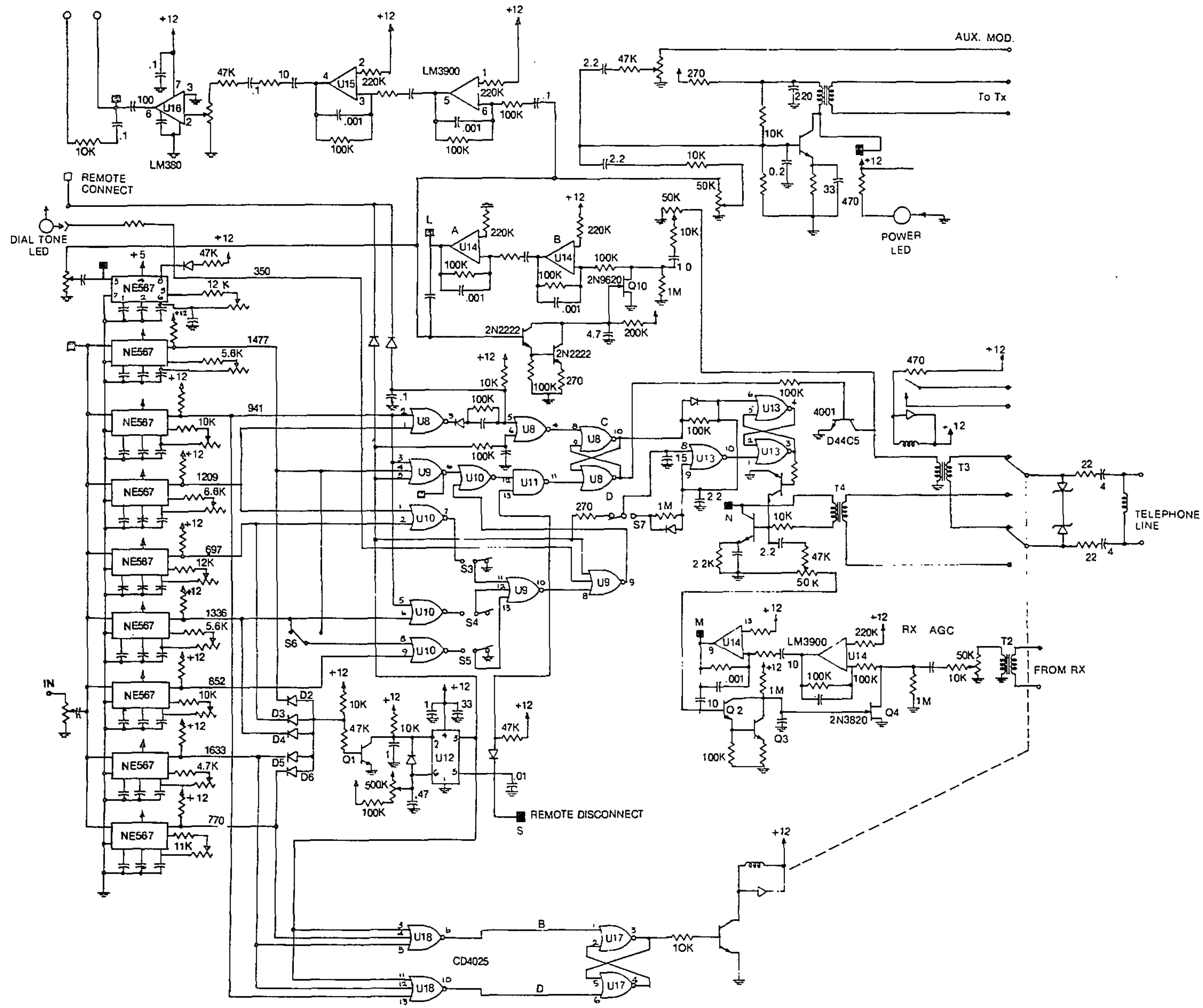


Figure 20. Modified RAP-400 Autopatch Unit

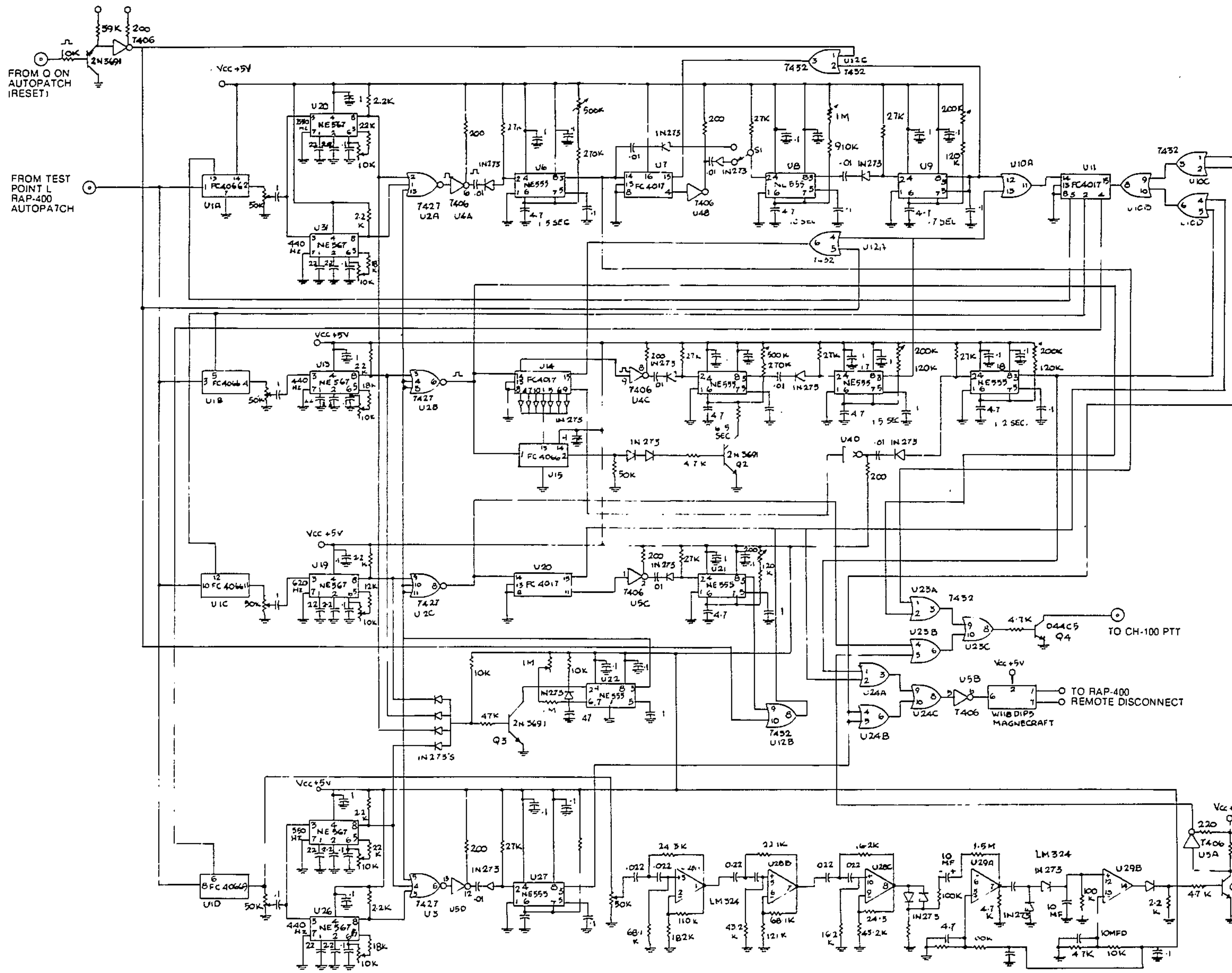


Figure 21. Transmitter Control Unit

4.3.5.1 Response to Dial Tone

Initially UIA will be open allowing the dial tone signal to be routed to the phase locked loop (PLL) tone decoders U30 and U31 which are tuned to the dial tone frequencies of 350 and 440 Hz respectively. During decoding, the outputs of U30 and U31 will go low triggering the validation timer U22. Validation occurs if the outputs of U30, U31 and U22 when presented to the coincidence detector U2A are all low simultaneously. A valid signal triggers timer U6 which has a cycling time of 1.5 seconds. The output of U6 closes the CH-100 PTT switch via the gates U23A, U23C and transistor Q4. Simultaneously, the dial tone signal is fed to the CH-100 modulator. As a result the dial tone is transmitted to the portable unit for 1.5 seconds. Upon hearing the dial tone, the portable unit operator will know that he has achieved "off-hook" conditions at the base station and that he can commence dialing.

Provision has been made for the connection of the system to either a regular "outside" or a "government line". When connected to an outside line, the calling party is required to dial only 7 digits for a local call. When connected to a government line, the number must be prefixed with the digit 9. In this case, the dial tone sounds immediately after "off-hook", is shut off briefly while the digit 9 is being dialed, and then becomes audible again. In this mode of operation selected by switch S1, the timer U6 will be triggered twice in succession transmitting a 1.5 second burst of dial tone each time and advancing counter U7 one position for each tone burst. After the completion of the second tone burst, the output of the counter U7 triggers the 10 second timer U8. During this 10 second period, the portable unit operator dials a 7 digit number. Upon completion of the 10 second period, U9 is triggered generating a one second pulse which simultaneously resets counter U7 to zero and advances counter U11 from 0 to 1. When this happens, gate U1A closes and U1B, U1C open.

4.3.5.2 Response to Ringing Signal

If the ringing signal is present, it will be decoded by the PLL U13 whose output will go low during each ring. After validation and inversion in U2B, the resultant high level advances counter U14 from its 0 to 1 position during the first ring. When this happens, gate U15 opens allowing any change in the output level of U2B to be transferred to transistor Q2 which is normally held off. In addition, the timer U16 is triggered and it starts to time out with a 6.5 second charging time commencing on the trailing edge of the ringing signal. During the time the ringing signal is present, the high at the output of U2B closes the CH-100 transceiver's PTT line via U23A, U23C and Q4 thereby transmitting the ringing signal to the portable unit. If no one answers the phone, the ringing signal continues, advancing the counter one step for each ring. The positive going level change associated with each ring causes Q2 to conduct resetting timer U16 before it times out. If the phone has not been answered after 9 rings, the counter U14 reaches its output position, pin 11, causing timer U18 to generate a 1 second pulse which disconnects the phone via U24A–C, U5B, and E1. This pulse also resets counter U11 to its 0 position closing gates U1B and U1C and opening gate U1A to await the next dial tone associated with a call. Meanwhile, timer U16 has timed out triggering U17 which generates a 1 second reset pulse. This is applied via gate U12A to counter U14 resetting it to 0.

If the phone is answered before counter U14 advances to its disconnect pin the ringing signal ceases allowing timer U16 to time out. At this instant, U17 is triggered, generating a one second pulse which simultaneously resets counter U14 to 0 and advances counter U11 to its "2" position. This causes gates U1A, B and C to close and gate U1D to open.

4.3.5.3 Response to Busy Signal

If a busy signal is present, it will be decoded by the PLL U19. After validation, the positive going level at the output of U2C will advance counter U20 one step for each busy tone burst and simultaneously close the CH-100 transceiver PTT switch thereby transmitting the busy signal to the portable unit. At the end of 9 busy tones, counter U20 will deliver a trigger pulse to timer U21 via inverter U5C. Timer U21 generates a one second positive pulse which resets counters U11 and U20 to 0 and disconnects the autopatch via U24A, C, U5B and E1. Resetting of counter U11 closes gates U1B, U1C, U1D and opens gate U1A in readiness for decoding the dial tone associated with the next call.

4.3.5.4 Response to an Answered Call

When the called party answers the phone the voice signal is applied to the VOX control circuit comprising U28, U29, Q5, U23B and U23C causing the PTT line in the CH-100 transceiver to close thereby transmitting the voice signal to the portable unit. There is, however, an initial delay of up to 6 seconds before this "voice-channel" becomes operative, and the telephone conversation can begin. This is due to the automatic disconnect circuitry, which hangs the phone up if not answered before 10 rings (see Section 4.3.5.2).

When the called party hangs up, after completing his conversation, the dial tone will come on after a period of 30 seconds. This will be decoded by the PLL's U25 and U26. After validation, timer U27 will be triggered generating a one second pulse which disconnects the autopatch via gates U24B–C, inverter U5B and relay E1. Counter U11 will also be reset via U10B and C. When this happens, gates U1B, C and D will be closed and gate U1A will be open to await the dial tone associated with the next call.

4.3.6 Base Station Antenna

The base station antenna is an inverted V. The antenna has a pattern similar to a half-wave dipole in the direction perpendicular to the plane of the antenna for horizontally polarized signals. The pattern along the axis of the antenna is similar to that of a half-wave dipole for high angle vertically polarized signals, except that there is radiation at the horizon (see Reference[1]).

5. COMMENT ON PERFORMANCE

As already noted, the VHF autopatch system described in this report has been in operational use in the Ottawa area since December 1977. It is currently being used by a group of radio amateurs as a public service emergency oriented autopatch repeater. Its reliability has therefore been amply demonstrated since there has been no significant equipment failure since it was installed.

The HF-SSB radio telephone interconnect system was developed to the point where, after limited field trial, the technical feasibility was clearly demonstrated (in September 1979). At this point, design/manufacture by industry was the logical next step and no further development and field trial of the prototype equipment was planned.

The reliability of the system is dependent on its resistance to falsing. While wrong numbers, or incomplete dialing can certainly occur due to signal fade or noise and interference, our field trial seemed to prove that successful dialing could be achieved if the circuit was "good enough" to "talk over".

Selective call systems based on the type of tone signaling adopted here using the simultaneous transmission of a pilot and information tone are commercially available. An equipment that has been tested by the authors is the Transworld Electronics Inc. type S3/S3M Selective Calling System. Three tone frequencies are used to encode the desired number into a digital format. A 1562 Hz reference tone together with a 1302 Hz tone represent the digit 0; the digit 1 is represented by the 1562 Hz reference tone and a 1202 Hz tone. The binary numbers thus formed are transmitted serially to form an 8 bit word. The digital bits are decoded at the receiver by taking the difference between the two tones comprising a particular digit; the difference frequencies are 260 Hz and 360 Hz respectively for the digits 0 and 1. They remain constant when the sideband frequencies or the re-injected carrier frequency shifts, and permit a frequency tolerance of ±500 Hz in SSB systems.

A quantitative comparison between the TWE S3/S3M selective calling system and the manually dialed system described in this report cannot be made precisely. The S3 system was designed to selectively call outstations from a control base station. The code time sequence for this equipment is 1.5725 seconds. The manually dialed system utilized a 1 second duration access code for "off-hook", and a 250 ms duration code for dialing. Consequently, the immunity of the systems to falsing under radio noise and interference is bound to differ.

The performance of the two systems were, however, compared: the signal-to-noise required to successfully "selectively call" with the S3/S3M system was compared with that for the manual dial system in its "access mode" of operation (i.e., access of the base station and achievement of dial tone). As noted above, the time constants for the two systems are 1.575 seconds and 1 second respectively. Various types and levels of "detected" audio frequency noise were recorded "on air" by a magnetic tape recorder for these tests. Since both systems operated at audio frequency, this is the noise environment that they are subject to in normal operational use. The comparisons lead to the following conclusions: (1) both systems were able to complete calls in noise or interference levels of 4–9 dB higher than the wanted signal level (semi-quantitatively measured with an oscilloscope). (2) both systems were more susceptible to falsing from radio teletype signals than from atmospheric noise, single sideband voice, or morse code (CW) signals; and (3) generally, the digitally encoded information system provided about 1.7 dB greater reliability averaged over the four different interference backgrounds; however, this is just about what should have been expected due to the different response times of the two systems.

6. CONCLUDING REMARKS

This report has described R&D carried out at the Communications Research Centre and in Canadian Industry during the past 5 years to develop simple inexpensive radio telephone interconnect systems that could be employed to improve communications from the trail and from remote camps by northern and native people. The research has culminated in the development and field trial of prototype systems which it is hoped will lead to design/manufacture of suitable equipment so that systems adapted to provide the kind of service desired by users are available for purchase. The HF/SSB system described herein has only had limited field trial. A commercial development of the type of system described in this report should be subject to extensive field trial in an operational environment, through collaboration with a telephone company; since the trail radio radio-to-telephone interconnect system would be interfaced with other equipment (satellite or radio relay) providing long distance dialing from the remote community.

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FM and Repeaters for Radio Amateurs, 117–125, American Radio Relay League, Inc., Newington, Conn., 1974.

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Spilsbury Communications Systems*, 120 East Cordova St., Vancouver, B.C., V6A 1L1

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* *Equipments/components manufactured by these companies were used in the prototype radio communication systems described herein.*

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