A $60 Programmable Talking Repeater Controller

This inexpensive programmable controller features stored voice, simplex or duplex repeater control, and low power consumption.

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Several recent repeater projects involving the construction of portable repeaters for disaster site use and building a repeater system with voted remote receivers indicated the need for a low-cost, easy-to-build repeater controller. The projects required a controller that could be built for less than $60, with enough features to be used as a duplex repeater controller, a link controller, or a simplex repeater controller. Other required features included remote control and programming via DTMF, a hang timer, time-out and ID timers, CW ID, and stored voice messages for all applications except link control. This article describes the product of our work: the $60 Repeater Controller.

Repeater Controller Mode

The controller has an ID timer which can trigger 1 of 2 stored voice IDs, or the CW ID. The IDs are controlled by a user-programmable ID timer, which can be set from 10 seconds to 2550 seconds. Normally this will be set to a value less than 600 seconds (the FCC-mandated 10 minute ID time.) The controller will play the "initial ID" if it has been quiet for one entire ID cycle (that is, the time specified by the ID timer has elapsed since the repeater's last transmission.) The initial ID might contain a message such as "Welcome to N1KDO repeater." The "normal ID" will play after the ID timer expires. The normal ID would typically contain a short ID message like "N1KDO repeater." The controller tries to be "polite" about when it IDs; if a user unkeys and the ID timer has 60 seconds or less remaining before playing an ID message, the controller will ID immediately in an attempt to keep the ID from playing on top of another user. If a user keys up while a stored voice ID is playing, the controller will cancel the stored voice ID and play the CW id. Also, if a user keys the repeater, and the controller plays the initial ID, the controller will not play the normal ID after the ID timer expires unless the repeater is keyed again. This prevents unnecessary IDing by the repeater.

The controller provides a hang timer and a courtesy tone. The hang timer keeps the repeater's transmitter on for a short time after a user unkeys. This reduces cycling of the repeater transmitter and can eliminate some of the squelch crashes on the user's that are caused by the repeater's transmitted signal dropping. The hang timer can be programmed for a delay from .1 second to 25.5 seconds. The courtesy tone is a short beep that sounds after a user's transmission has ended and the time-out timer has been reset. (Note that the time-out timer is reset before the courtesy tone is heard.)

The controller has a user-programmable time-out timer, which can be set from 1 second to 255 seconds. The time-out timer prevents damage to the repeater's transmitter in the event of a user

sitting down on his microphone before starting a long ride, or the repeater's receiver becoming unsquelched for some reason. The time-out message plays when the time-out timer expires and when the time-out condition ends, so people listening to the repeater are aware of the time-out condition as soon as it happens, and the offending operator knows that he timed out the repeater when the time-out condition ends.

A tail message can be selected to play after a programmed number of expirations of the hang timer. This message can be used to advertise a net or club meeting, to warn of inclement weather, etc.

Link Controller Mode

The controller can be used to control link radios for remote receivers or split-site repeaters. In link controller mode, the controller does not use any stored voice messages; it only will ID in CW. This allows the controller to be built without the ISD1420 and associated support circuitry, lowering the cost for link support. In most link controller modes, the hang time would be set to zero.

Simplex Repeater Controller Mode

The controller can also be used to run a "simplex repeater". A simplex repeater records up to twenty seconds of audio from the receiver, then plays the recorded audio back out the transmitter. In this mode, the controller will ID in CW when the ID timer expires.

Power Consumption

The controller is ideal for remote solar and battery powered applications. In standby mode, less then 10 mA of current is drawn. Worst case current consumption occurs when messages are recorded into the ISD1420 chip, and that is under 30 mA. Normal repeater operation requires less than 20 mA.

Circuit Description

The controller consists of a Microchip PIC 16C84 microcontroller IC, a Mitel/Teltone M8870 DTMF decoder IC, a ISD 1420 voice record/playback IC, and a CMOS operational amplifier IC.

The heart of the controller is the Microchip PIC 16C84 microcontroller (U1). The 16C84 features 13 I/O leads, 1024 word of program storage, 36 bytes of RAM, and 64 bytes of EEPROM (non-volatile memory) in a 18-pin DIP. It is a RISC-like (reduced instruction set computer) Harvard architecture computer (it has separate program and data stores), and is extremely fast. In the repeater controller application, the PIC 16C84 executes over 800,000 instructions per second (.8 MIP!). The 16C84 provides all the timers, CW generation, DTMF validation, and other digital I/O requirements of the controller. The 16C84 uses the 3.58 MHz clock generated by the DTMF decoder.

DTMF tones are decoded by the Mitel/Teltone M8870 (U3). The M8870 decodes DTMF by filtering the received audio signal into its high and low components, and counting the frequency

of each component. Because it uses this approach, it is much less likely to detect voice as a DTMF digit and generate a false decode. When a valid digit is decoded, the M8870 raises the StD (delayed steering) lead, which informs the 16C84 microcontroller that a valid touch tone has been received.

Speech messages are stored in the ISD 1420 (U2). This device stores speech by recording analog levels into flash EEPROM cells, rather than storing digital values. The ISD1420 can address up to 160 different messages of 125 ms each, but in the controller application, we chose to implement 4 messages of approximately 5 seconds each. The device's address lines are configured to allow messages to start at the 0-, 5-, 10-, and 15-second addresses. Device address, playback and record are controlled by the PIC 16C84.

Audio processing uses an optional de-emphasis circuit that provides a -6dB/octave slope to de-emphasize receiver audio, which allows the controller to be fed with the receiver's discriminator output, rather than an already deemphasized source of audio, such as a line or speaker output. A FET(Q1) mutes the audio when the receiver is squelched or DTMF tones are present. A simple audio mixer combines receiver audio, ISD 1420 audio, and beep tone audio into the transmitter input.

Software Description

The controller's PIC 16C84 microcontroller chip would do absolutely nothing without software. The controller's software handles all DTMF validation, beep generation, timing, CW sending and control required by the ISD1420 and the repeater itself. The source code is nearly 1500 lines of assembler, and uses 85% of the available program storage on the PIC. The program uses 32 of 36 bytes of RAM on the PIC, and more than half of the EEPROM. The operation of the software can be loosely described as a polled loop, with interrupt-based timing. The source code is heavily commented for easy modification within the remaining space on the PIC.

The controller's software was assembled with Microchip's MPASM. The source and object code are available for unlimited non-commercial use by amateurs worldwide, and can be downloaded from the Internet. Development tools for the PIC microcontroller (MPASM and MPSIM) are also available on the Internet. Several sources exist on the Internet that describe the construction of a programmer for the PIC 16C84. (See "Sources", below.)

Radio Interfacing

The controller uses a female DB9 connector for all signals. It requires receiver audio and a signal present indication (CAS) from the receiver, Transmit audio and PTT for the transmitter, and 13.8 volts DC for power. Be very careful when wiring DC power to the controller, reverse polarity will destroy the ICs.

Table 1:
DB9 Connector Pinout

Pin	Signal
1	Ground
2	13.8 Volts
3	PTT (active low)
4	TX Audio
5	RX Audio
6	CAS +
7	CAS -
8	Ground/TX Audio Return
9	Ground/RX Audio Return

Receiver audio can typically be taken from the high side of the squelch control. This audio must be de-emphasized with the controller's optional de-emphasis circuit, which provides a -6dB/octave slope. Optionally, audio can be taken from later in the receiver's audio chain, where it is already de-emphasized. Care must be taken that this source of audio is not subject to adjustment by the radio's volume control. If the receiver audio has not been properly de-emphasized, either in the receiver itself, or on the controller board, the repeater will have a very "tinny", unnatural sound to it.

To de-emphasize the receiver audio on the controller board, install a .0068 F capacitor in position C3, change R3 to 51K, and change R4 to 510K. These values should be considered a good starting point; you may want to experiment with the values of C3 and R4 to get better sounding audio. We have had consistently good results with this de-emphasis network.

The receiver must provide a signal present indication (also called COR, RUS, CAS) to the controller. Because of the varieties of polarity and state that this signal can take, we have chosen to implement the controller's signal present input with an opto-isolator (ISO1). The anode and cathode of the LED in the opto-isolator are exposed through a current limiting resistor (R30). This allows easy interfacing to active-high, active-low, and combinations of both to indicate the presence of a received signal to the controller. Clever wiring can allow the user to create CTCSS and COR, CTCSS or COR, etc. configurations.

Transmitter audio can be fed directly into the microphone input of the transmitter. VR2 is the master level control, used to set the audio level into the transmitter. Transmit audio should be adjusted with a service monitor or deviation meter.

Transmitter keying is provided by a power MOSFET (Q6) configured in an open-drain circuit. This can be used to key many transmitters directly. The MOSFET essentially provides a closure to ground for PTT. For other transmitters, the MOSFET can drive a small relay to key the radio. Although this MOSFET can handle several amps, we recommend that no more than 100 mA of current be drawn through it, since the trace on the PC board is rather thin.

Adjusting the Audio Levels

Preset all potentiometers to midrange. Connect an oscilloscope probe or DVM to pin 15 of U3. (Use the power supply ground for the 'scope's ground or the DVM's return.) Key a radio on the input frequency, send some touch-tones, and adjust VR1 (the main receive level) until DTMF decoding is reliably indicated by a 5 volt level on U3 pin 15. Disconnect the oscilloscope or DVM. Adjust VR2 (the master level) to adjust transmitter deviation, ideally measured with a deviation meter or service monitor. Adjust VR6 (the beep level) to set the courtesy tone and CW tone level.

The easiest way to adjust the ISD1420 input and output levels is to select the simplex repeater mode and record messages until the audio sounds right. VR3 adjusts the record audio level into the ISD1420. Adjust this control for the best sounding record audio. VR5 sets the ISD1420 playback level. Adjust this control for best acceptable transmitter deviation. VR4 is used to set the receiver audio level, and may not need to be adjusted from midpoint.

Initializing the Controller

To initially program your secret code into the controller, you must apply power to the controller with the pins on the Init jumper, (SW1) shorted, putting the controller into the initialize mode. Remove the jumper a few seconds after power is applied. All of the values stored in the EEPROM will be reset to defaults, and the controller will be ready to accept the 4-digit secret access code. This will reset the CW ID to the default value "DE NHRC/2" as well. When the controller is in the initialize mode the courtesy tone is 1/2 second long, instead of the usual 1/5 second. Key up and enter your 4-digit access code. The controller should respond with the normal (1/5 second) courtesy beep. The secret access code is stored in non-volatile memory in the 16C84 microcontroller. You will use this code as the prefix for all commands you send to the controller.

About Hexadecimal

To save space and reduce software complexity, the controller is programmed using hexadecimal, or hex for short. Hex is a base-16 notation that is particularly convenient for use in digital computer systems because each hex digit represents 4 bits of a value. The controller uses pairs of hex digits to represent 8-bit values for the address and data of programming information. Any decimal number from 0 to 255 may be represented by two hex digits. Hex digits are 0, 1, 2, 3, 4,

5, 6, 7, 8, 9, A, B, C, D, E, F, where A through F represent values from 10 to 15. To convert a decimal number from 0 to 255 to hex, divide the decimal number by 16. The quotient (number of whole 16s) forms the left (high) digit, and the remainder forms the right (low) digit. Thus, 60 decimal = 3 x 16 + 12 = 3C hex.

Programming the Controller

All programming data is entered into the controller as DTMF strings of 4 hex digits immediately after the access code is entered. The * tone is translated to hex "E", and the # code is translated to hex "F". The first two hex digits represent a memory location, and the second two digits represent a value to store in that location. This probably sounds more complicated than it is. For example, to program the hang timer (address 04) with 5 seconds (50 decimal = 32 hex), assuming your secret code is 1234, you would key your radio, enter 1, 2, 3, 4, 0, 4, 3, 2, then unkey. If the OK message had been programmed, the controller will respond with the CW message "OK". The if the NG message has been programmed, and the address entered was not valid, the controller will respond with the CW message "NG". The range of valid addresses is 00-3F. The controller uses 40 and 41 for message play and record commands as described in Table 2:

Table 2: Message Play/Record Commands

Command	Description
400x	0 <= x <= 3, play CW message x
401x	0 <= x <= 3, play voice message x
410x	0 <= x <= 3, record voice message x

Timers in the controller are of three different resolutions, depending on the application. All timers are stored in 8-bit values, and can hold any value from 0 to 255. The hang timer is in one-tenth second increments. To program a hang time of 5 seconds, the value 50 decimal must be stored in the hang timer preset location. To store the value, it must first be converted to hexadecimal. 50 decimal translates to 32 hex. Therefore, the command sent to then controller would be "cccc0232" to set the hang time to 5.0 seconds, where "cccc" is your secret access code. The hang time can be adjusted from 0 to 25.5 seconds.

The time-out timer is in whole second increments. 60 seconds would be stored as 60 decimal (3c hex). The time-out timer can be adjusted from 0 to 255 seconds.

The ID timer is in ten-second increments. To store 570 seconds (9.5 minutes) you would store 57 decimal (39 hex). The ID timer can be set from 0 to 2550 seconds!

Messages

Stored voice messages up to 4.8 seconds each can be recorded. The controller will not play the last 100 ms of stored messages to avoid playing squelch crashes that may have been recorded at the end of the messages. CW messages play at 12 WPM. There are 4 messages for voice, and 4 messages for CW, as shown in Table 3:

Table 3: Message Numbers

Message Number	Stored Voice	CW
0	Initial ID	ID message
1	Normal ID message	timeout message ("TO")
2	Time-out Message	confirm message ("OK")
3	Tail Message	invalid message ("NG")

Recording the Voice Messages

To record the voice message, enter your secret code, then 410x, where X is the number of the voice message you wish to program. Unkey after the command sequence, then key up, speak your message, and unkey. The controller will remove about 100 ms from the end of your message to remove any squelch crash that might have been recorded. You can play your message by using command 401x, where x is the number of the voice message you want to play. The tail message is recorded like any other message, but it will not play until you program the tail message counter (address 05) to a non-zero value N. Programming the tail message counter to 0 will disable the tail message.

You may wish to have a family member or member of the opposite sex record your ID messages. The recorded audio sounds natural enough that people have actually tried to call the amateur who's callsign is recorded in the controller after the ID message plays!

Programming CW Messages

CW messages are stored in the controller's non-volatile memory, and programmed in the same manner as the timers. Each message has a fixed base address, and maximum number of characters. Refer to Table 4, the programming memory map to determine where each symbol in a message belongs. CW symbols are stored in a binary-encoded form, from right to left, with a 1 representing a dah, and a 0 representing a dit. The leftmost 1 indicates the width of the symbol. Table 5 has been provided as a quick lookup of the CW symbols to their encoded hexadecimal form. To program the first letter of the ID message ("D"), you would enter your secret code, then the address (0E), then the encoded form of the letter D (09): "cccc0909" (where cccc represents

your secret access code). To program the second letter ("E") enter "cccc0F02". The ID message can be up to 39 characters long, and must end with the End-Of-Message character, hex FF.

About the IDs

The controller will normally play the initial ID when the repeater is first accessed after one ID period of inactivity. If no further activity occurs after the initial ID plays, then no ID will be sent after the ID timer expires. If any activity occurs after the initial ID is sent, the first occurrence will set the ID timer. If a user unkeys within 60 seconds of the expiration of the ID timer, the repeater will play the normal ID message immediately, hopefully to prevent it from playing during another user's transmission. If a user keys up the repeater when a voice ID is playing, the controller will cancel the playing voice ID and start to play the CW ID. The CW ID cannot be canceled.

Selecting Controller Modes

The controller mode is selected by programming values into the configuration flags (address 01). Multiple modes can be simultaneously selected by adding their values together to set multiple bits in the configuration byte. To select "normal" (full-duplex) controller mode, program the configuration flags with 00. To select link controller mode (no ISD1420, only CW messages), program the configuration flags byte with 01, and optionally program the hang timer (address 02) to 00. When in link controller mode, you may wish to have the controller pass DTMF tones to a "downstream" controller. Program the configuration flags byte with 21 in this case. To select the simplex repeater controller mode, program the configuration flags byte with 02. In normal or link control mode, the courtesy tone can be suppressed by adding hex 10 to the configuration flags. For instance, to use link controller mode with no courtesy tone, program the configuration flags with 11. Note that in either normal or link control mode, setting the hang time to 0 will also suppress the courtesy tone. The tail message stored in position 3 can be used instead of the courtesy beep by adding hex 40 to the controller mode byte. See Table 6 for a description of the various bits in the configuration flags byte.

Table 6: Configuration Flag Bits

Bit	Hex Weight	Feature
0 (LSB)	01	ISD Absent
1	02	Simplex repeater mode
2	04	N/A
3	08	N/A
4	10	suppress courtesy tone

5	20	suppress DTMF muting
6	40	use Tail Message for courtesy tone
7 (MSB)	80	N/A

RFI

Radio Frequency Interference (RFI) is everywhere, but is particularly troublesome at a repeater site. This controller, like any microprocessor-based device, can generate a significant amount of RFI. It is important to install the controller into a grounded RF-tight box.

Conclusion

We found that the low cost, variety of features, and low power consumption of this controller made it a winner for several of our repeater projects. We wanted to share our results with the amateur community at large, and hope that many of you will find this controller useful and functional in your own repeater projects.

Table 4: Programming Memory Map

Address	Default Data	Comment
00	01	enable flag
01	00	configuration flags
02	32	hang timer preset, in tenths
03	1e	time-out timer preset, in seconds
04	36	id timer preset, in 10 seconds
05	00	tail message counter
06	0f	'O' OK Message
07	0d	'K'
08	ff	EOM
09	05	'N' NG Message
0a	0b	'G'

0b	ff	EOM
0c	03	'T' TO Message
0d	0f	'O'
0e	ff	EOM
0f	09	'D' CW ID starts here
10	02	'E'
11	00	space
12	05	'N'
13	10	'H'
14	0a	'R'
15	15	'C'
16	29	'/'
17	3c	'2'
18	ff	EOM
19	ff	EOM
1a	ff	EOM
1b-37		not used, room for long CW ID
38	n/a	isd message 0 length, in tenths
39	n/a	isd message 1 length, in tenths
3a	n/a	isd message 2 length, in tenths
3b	n/a	isd message 3 length, in tenths
3c	n/a	passcode digit 1
3d	n/a	passcode digit 2

3e	n/a	passcode digit 3
3f	n/a	passcode digit 4

Morse Code Encoding.

Morse code characters are encoded in a single byte, bit-wise, LSB to MSB. A 0 represents a dit and a 1 represents a dah. The byte is shifted out to the right, until only a 1 remains. Characters with more than 7 elements (like error) cannot be sent. Special cases are made for space (hex 00) and end-of-message (hex ff).

Table 5: Morse Code Character Encoding

Character	Morse Code	Binary Encoding	Hex Encoding
SK	. . . - . -	01101000	68
AR	. - . - .	00101010	2a
BT	- . . . -	00110001	31
/	- . . - .	00101001	29
0	- - - - -	00111111	3f
1	. - - - -	00111110	3e
2	. . - - -	00111100	3c
3	. . . - -	00111000	38
4	. . . . -	00110000	30
5	. . . . .	00100000	20
6	-	00100001	21
7	- - . . .	00100011	23
8	- - - . .	00100111	27
9	- - - - .	00101111	2f

a	.-	00000110	06
b	-...	00010001	11
c	-.-.	00010101	15
d	-..	00001001	09
e	.	00000010	02
f	..-.	00010100	14
g	--.	00001011	0b
h	....	00010000	10
i	..	00000100	04
j	.---	00011110	1e
k	-.-	00001101	0d
l	.-..	00010010	12
m	--	00000111	07
n	-.	00000101	05
o	---	00001111	0f
p	.--.	00010110	16
q	--.-	00011011	1b
r	.-.	00001010	0a
s	...	00001000	08
t	-	00000011	03
u	..-	00001100	0c
v	...-	00011000	18
w	.--	00001110	0e

x	-..-	00011001	19
y	-.--	00011101	1d
z	--..	00010011	13
space		00000000	00
EOM		11111111	ff

References

- PIC 16/17 Microcontroller Data Book. Microchip Corporation, Chandler AZ. *(http://www.microchip.com)*
- ISD Data Book, Voice Record and Playback ICs, 1995. Information Storage Devices, San Jose, CA. *(http://www.isd.com)*
- Telecom Design Solutions, Component Data Book. Teltone Corporation, Bothell, WA *(or see http://www.semicon.mitel.com/Products.html)*
- Application Note MSAN-108, "Applications of the MT8870 Integrated DTMF Receiver". Mitel Semiconductor, Kanata, Ontario, Canada *(http://www.semicon.mitel.com)*
- Linear Circuits Data Book 1992, Volume 1, Operational Amplifiers. Texas Instruments, Dallas, TX. *(or see http://www.st.com)*

Sources

- The source code for the repeater controller is available on the Internet from the following location: *http://www.nhrc.net*. The source code is also available from N1KDO, send a blank diskette and a stamped, self-addressed diskette mailer.
- A partial parts kit, containing a programmed PIC16C84, M8870, and the PC board (the parts that are not available from Digi-Key) is available for $25, plus $5 for shipping (international shipping extra), from NHRC.
- PIC16C84 device programmer information is available on the Internet at the following locations:
    - *http://digiserve.com/takdesign/pic-faq/hardware.html*
    - *http://www.paranoia.com/~filipg/HTML/LINK/ELE/F_PIC_faq.html*

- *http://hertz.njit.edu/~rxy5310/picb*

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Mail comments to *otterson@nhrc.net*

NHRC-2 Repeater Controller
User Guide

Contents

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1. Installation

1. Electrical Connections

The controller uses a female DB9 connector for all signals. It requires receiver audio and a signal present indication (CAS) from the receiver, supplies transmit audio and PTT to the transmitter, and requires 13.8 volts DC for power. Be very careful when wiring DC power to the controller, reverse polarity will destroy the ICs. The connector pinout is shown in the table below.

Electrical Connections

Pin	Use
1	Ground
2	+13.8 Volts
3	PTT (active low)
4	TX Audio
5	RX Audio
6	CAS +
7	CAS -
8	Ground/TX Audio Return
9	Ground/RX Audio Return

Receiver audio can typically be taken from the high side of the squelch control. This audio must be de-emphasized with the controller's optional de-emphasis circuit, which provides a -6dB/octave slope. Optionally, audio can be taken from later in the receiver's audio chain, where it is already de-emphasized. Care must be taken that this source of audio is not subject to adjustment by the radio's volume control. If the receiver audio has not been properly de-emphasized, either in the receiver itself or on the controller board, the repeater will have a very "tinny", unnatural sound to it.

To de-emphasize the receiver audio on the controller board, install a .0068 F capacitor in position C3, change R3 to 51K, and change R4 to 510K. These values should be considered a good starting point. You may want to experiment with the values of C3 and R4 to get better sounding audio. We have had consistently good results with this de-emphasis network.

The receiver must provide a signal present indication (also called COR, RUS, CAS) to the controller. Because of the varieties of polarity and state that this signal can take, we have chosen to implement the controller's signal present input with an opto-isolator (ISO1). The anode and cathode of the LED in the opto-isolator are exposed through a current limiting resistor (R30). This allows easy interfacing to active-high, active-low, and combinations of both to indicate the presence of a received signal to the controller. Clever wiring can allow the user to create CTCSS and COR, CTCSS or COR, etc. configurations. Note that **both** the CAS+ and CAS- terminals must be connected to something in order for the controller to detect the signal present indication.

Transmitter audio can be fed directly into the microphone input of the transmitter. VR2 is the master level control, used to set the audio level into the transmitter. The transmitter's deviation limiter (sometimes called IDC) should be set such that the transmitter cannot overdeviate, regardless of input signal level. One way to adjust transmitter deviation is to set the transmitter deviation limiter wide open (unlimited), adjust the controller's master output until the transmitter is slightly overdeviating, then set the transmitter's deviation limiter to limit just below 5 KHz deviation. Then reduce the controller's master output until the transmitted audio does not sound compressed or clipped. Transmitter deviation should be adjusted with a service monitor or deviation meter.

Transmitter keying is provided by a power MOSFET (Q6) configured in an open-drain circuit. This can be used to key many transmitters directly. The MOSFET essentially provides a closure to ground for PTT. For other transmitters, the MOSFET can drive a small relay to key the radio. Although this MOSFET can handle several amps, we recommend that no more than 100 mA of current be drawn through it, because the trace on the PC board is rather narrow.

2. Adjusting the Audio Levels

Preset all potentiometers to midrange. Connect an oscilloscope probe or DVM to pin 15 of U3 (the M8870 DTMF decoder). (Use the power supply ground for the 'scope's ground or the DVM's return.) Key a radio on the input frequency, send some touch-tones, and adjust VR1 (the main receive level) until DTMF decoding is reliably indicated by a 5-volt level on U3 pin 15. Disconnect the oscilloscope or DVM. Adjust VR2 (the master level) to adjust transmitter deviation, ideally measured with a deviation meter or service monitor. Adjust VR6 (the beep level) to set the courtesy tone and CW tone level.

The easiest way to adjust the ISD1420 input and output levels is to select the simplex repeater mode and record messages until the audio sounds right. VR3 adjusts the record audio level into the ISD1420. Adjust this control for the best sounding record audio. VR5 sets the ISD1420 playback level. Adjust this control for best acceptable transmitter deviation. VR4 is used to set the receiver audio level, and may not need to be adjusted from midpoint.

3. Initializing the Controller

To initially program your secret code into the controller, you must apply power to the controller with the pins on the init jumper, (SW1) shorted, putting the controller into the initialize mode. Remove the jumper a few seconds after power is applied. All of the values stored in the EEPROM will be reset to defaults, and the controller will be ready to accept the 4-digit secret access code. This will reset the CW ID to the default value "DE NHRC/2" as well. When the controller is in the initialize mode the courtesy tone is 1/2 second long, instead of the usual 1/5 second. Key up and enter your 4-digit access code. The controller should respond with the normal (1/5 second) courtesy beep. The secret access code is stored in non-volatile memory in the 16C84 microcontroller. You will use this code as the prefix for all commands you send to the controller.

2. Programming

1. Controller Modes

The controller can operate in 3 different modes:

- Repeater Controller Mode
  The controller operates a full-duplex repeater, with a courtesy tone and stored voice messages.

- Link Controller Mode
  This is a variation of Repeater Controller Mode where the ISD1420 voice storage chip is deleted to lower the cost of the controller. This mode is intended to control remote receivers that are essentially crossband repeaters. Normally, when using link controller mode, the hang time is set to 0 seconds, and the controller is programmed to suppress DTMF muting, so the user's DTMF commands will appear on the input of a "downstream" controller. The controller adds remote control, a timeout timer and CW ID capability to remote or link receivers.

- Simplex Repeater Controller Mode
  This mode allows simplex (as opposed to duplex) radios to be used as repeaters. Up to 20 seconds of received audio is stored in the ISD1420 voice storage chip, and is "parroted" back when the user unkeys. The ID message is played in CW.

2. Programming the Controller

All programming is done by entering 8-digit DTMF sequences. The first 4 digits are the *passcode* chosen at initialization. The next 2 digits are an *address* or a *function code*. The last 2 digits are the *data* for address or function. To enter programming information, you must key your radio, enter the 8 digits, then unkey. If the controller understands your sequence, it will respond with "OK" in CW. If there is an error in your sequence, but the passcode is good, the controller will respond with "NG". If the controller does not understand your command at all, it will not respond with anything other than a courtesy beep, and then only if the courtesy beep is enabled.

Responses to Commands

Response	Meaning
"OK"	Command Accepted
"NG"	Command address or data is bad
courtesy beep or nothing	Command/password not accepted

If you enter an incorrect sequence, you can unkey before all 8 digits are entered, and the sequence will be ignored. If you enter an incorrect address or incorrect data, just re-program the location affected with the correct data.

In order to save space, reduce keystrokes, and eliminate some software complexity, all programming addresses and data are entered as hexadecimal numbers. Hexadecimal (or hex, for short) is a base-16 notation that is particularly convenient for use in digital computer systems because each hex digit represents 4 bits of a value. The controller uses pairs of hex digits to represent 8-bit values for the address and data of programming information. Any decimal number from 0 to 255 may be represented by two hex digits. Hex digits are 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F, where A through F represent values from 10 to 15. To convert a decimal number from 0 to 255 to hex, divide the decimal number by 16. The quotient (number of whole 16s) forms the left (high) digit, and the remainder forms the right (low) digit. Thus, 60 decimal = 3 x 16 + 12 = 3C hex.

The DTMF keys 0-9 and A-D map directly to their corresponding digits. Use the ***** key for digit **E** and the **#** key for digit **F**. A 16-key DTMF generator is required to program the controller.

1. Programming the Timers

Timer Resolution. The timer values are stored as an 8-bit value, which allows a range of 0 to 255. Some of the timers require high-resolution timing of short durations, and others require lower resolution timing of longer durations. Therefore, timers values are scaled by either 1/10, 1, or 10 seconds, depending on the application.

Timer Address and Resolution

Timer	Address	Resolution Seconds	Max. Value Seconds
Hang Timer	02	1/10	25.5
Timeout Timer	03	1	255
ID Timer	04	10	2550

Enter the 4 digit passcode, the timer address, and the timer value, scaled appropriately. For example, to program the Hang Timer for 10 seconds, enter *pppp0264*, where *pppp* is your secret passcode, 02 is the hang timer address, and 64 is the hexadecimal value for 100, which would be 10.0 seconds.

2. Programming the CW Messages

CW messages are programmed by storing encoded CW characters into specific addresses in the controller. Use the Morse Code Character Encoding table and the Programming Memory Map to determine the data and address for the CW message characters. For example, to program "DE N1KDO/R" for the CW ID, you would use the following commands:

DTMF Command	Address	Data	Description/Purpose
*pppp*0#09	0F	09	D
*pppp*1002	10	02	E
*pppp*1100	11	00	space
*pppp*1205	12	05	N
*pppp*133*	13	3E	1
*pppp*140D	14	0D	K
*pppp*1509	15	09	D
*pppp*160#	16	0F	O
*pppp*1729	17	29	/
*pppp*180A	18	0A	R
*pppp*19##	19	FF	End of message marker

The CW ID can store a message of up to 40 characters. Do not exceed 40 characters.

3. Programming the Flag Bits

Controller features can be enabled of disabled with the use of the Configuration Flag Bits. These bits are encoded into a single byte, which is programmed into the controller at address 01. Multiple flag bits can be selected by summing their hex weights. For instance, to set up a link controller with no ISD1420, no courtesy tone, and suppress the DTMF

muting, you would add 01, 10, and 20 to produce hex 31, which you would then program into address 01 in the controller as *pppp*0131.

Configuration Flag Bits

Bit	Hex Weight	Feature
0	01	ISD Absent
1	02	Simplex repeater mode
2	04	n/a
3	08	n/a
4	10	suppress courtesy tone
5	20	suppress DTMF muting
6	40	use tail message for courtesy tone
7	80	n/a

4. Recording the Voice Messages

Stored voice messages can be played and recorded, and CW messages can be played by using the message commands. Command 40 is used to play stored voice or CW messages, and command 41 is used to record stored voice messages.

To record stored voice messages, use command *pppp*410*x*, where *x* is the number of the message you want to record, found in the message contents table. Unkey after the command sequence, then key up, speak your message, and unkey. The controller will remove about 100 ms from the end of your message to remove any squelch crash that might have been recorded.

To play stored voice messages, use command *pppp*401*x*, where *x* is the number of the stored voice message you want to play. To play CW messages, use command *pppp*401*x*, where *x* is the number of the CW message you want to play.

You may wish to have a family member or member of the opposite sex

record your ID messages. The recorded audio sounds natural enough that people have actually tried to call the amateur whose callsign is recorded in the controller after the ID message plays!

3. Enabling/Disabling the Repeater

The repeater can be disabled or enabled by remote control by setting the value in location 00. Set this location to zero to disable, or non-zero to enable. For instance, to disable the repeater, send command *pppp*0000. To enable the repeater, send command *pppp*0001.

3. Operating

1. About the IDs

When the repeater is first keyed the controller will play the "initial ID". If the repeater is keyed again before the ID timer expires, the controller will play the "normal ID" when the ID timer expires. If the repeater is not keyed again, and the ID timer expires, the controller will reset and play the "initial ID" the next time the repeater is keyed. If the repeater is keyed while the controller is playing a stored voice message ID, the controller will cancel the stored voice message ID and play the CW ID.

The idea behind this IDing logic is to prevent unnecessary IDing. For instance, if a repeater user keys the machine and announces "This is N1KDO, monitoring", the controller will play the initial ID, and no further IDing will occur unless the repeater is keyed again. If users commence with a QSO, keying the repeater at least once more, the controller will play the normal ID and reset the ID timer when the ID timer expires. If the repeater becomes idle for one ID timer period after the last ID, then the next time it is keyed it will play the initial ID. The intent is that the repeater users only hear the initial ID the first time that they key the repeater.

2. The Tail Message

The controller supports a "Tail Message" that plays the *n*th time the hang timer expires. The number of times the hang timer must expire before the tail message plays (*n*) is the "tail message counter" at address 5. The tail message counter can be set from 1 to 255. The tail message is disabled if the tail message counter is set to 0. Program the tail message counter value into address 05.

3. Using the Tail Message as the Courtesy Tone

The tail message can be used as the courtesy tone if bit 6 is set in the configuration flags. In this case, you will likely want to set the tail message counter value to 0 to keep the message from playing twice occasionally. The message could store the sound of a bell, a dog's bark, or the repeater trustee saying "what?"!

Tables

Message Commands

Command	Description
400x	0 <= x <= 3, play CW message x
401x	0 <= x <= 3, play voice message x
410x	0 <= x <= 3, record voice message x

Message Contents

Message Number	Stored Voice	CW
0	Initial ID	ID message
1	Normal ID message	timeout message ("TO")
2	Time-out Message	confirm message ("OK")
3	Tail Message	invalid message ("NG")

Programming Memory Map

Address	Default Data	Comment
00	01	enable flag
01	00	configuration flags
02	32	hang timer preset, in tenths
03	1e	time-out timer preset, in seconds
04	36	id timer preset, in 10 seconds
05	00	tail message counter
06	0f	'O' OK Message
07	0d	'K'
08	ff	EOM
09	05	'N' NG Message
0a	0b	'G'
0b	ff	EOM
0c	03	'T' TO Message
0d	0f	'O'
0e	ff	EOM
0f	09	'D' CW ID starts here
10	02	'E'
11	00	space
12	05	'N'
13	3e	'1'
14	0d	'K'

15	09	'D'
16	0f	'O'
17	29	'/'
18	0a	'R'
19	ff	EOM
1a	00	can fit 6 letter ID....
1b-37		not used
38	n/a	isd message 0 length, in tenths
39	n/a	isd message 1 length, in tenths
3a	n/a	isd message 2 length, in tenths
3b	n/a	isd message 3 length, in tenths
3c	n/a	passcode digit 1
3d	n/a	passcode digit 2
3e	n/a	passcode digit 3
3f	n/a	passcode digit 4

Morse Code Character Encoding

Character	Morse Code	Binary Encoding	Hex Encoding
sk	. . . - . -	01101000	68
ar	. - . - .	00101010	2a
bt	- . . . -	00110001	31
/	- . . - .	00101001	29

0	- - - - -	00111111	3f
1	. - - - -	00111110	3e
2	. . - - -	00111100	3c
3	. . . - -	00111000	38
4	. . . . -	00110000	30
5	. . . . .	00100000	20
6	-	00100001	21
7	- - . . .	00100011	23
8	- - - . .	00100111	27
9	- - - - .	00101111	2f
a	. -	00000110	06
b	- . . .	00010001	11
c	- . - .	00010101	15
d	- . .	00001001	09
e	.	00000010	02
f	. . - .	00010100	14
g	- - .	00001011	0b
h	. . . .	00010000	10
i	. .	00000100	04
j	. - - -	00011110	1e
k	- . -	00001101	0d
l	. - . .	00010010	12
m	- -	00000111	07

n	-.	00000101	05
o	---	00001111	0f
p	.--.	00010110	16
q	--.-	00011011	1b
r	.-.	00001010	0a
s	...	00001000	08
t	-	00000011	03
u	..-	00001100	0c
v	...-	00011000	18
w	.--	00001110	0e
x	-..-	00011001	19
y	-.--	00011101	1d
z	--..	00010011	13
space		00000000	00
EOM		11111111	ff

NHRC-2 Repeater Controller BOM

Item	Qty.	Ref.	Value	Description	Pkg.	Mfg.	Mfg. P/N	Digi-Key P/N	Unit Cost	Notes
1	11	C1	0.1uF	0.1uF 50V Z5U Ceramic Capacitor		Panasonic	ECU-S1H104MEA	P4924-ND	$ 0.21	
		C4	0.1uF	0.1uF 50V Z5U Ceramic Capacitor		Panasonic	ECU-S1H104MEA	P4924-ND	$ 0.21	
		C5	0.1uF	0.1uF 50V Z5U Ceramic Capacitor		Panasonic	ECU-S1H104MEA	P4924-ND	$ 0.21	
		C6	0.1uF	0.1uF 50V Z5U Ceramic Capacitor		Panasonic	ECU-S1H104MEA	P4924-ND	$ 0.21	
		C18	0.1uF	0.1uF 50V Z5U Ceramic Capacitor		Panasonic	ECU-S1H104MEA	P4924-ND	$ 0.21	
		C19	0.1uF	0.1uF 50V Z5U Ceramic Capacitor		Panasonic	ECU-S1H104MEA	P4924-ND	$ 0.21	
		C21	0.1uF	0.1uF 50V Z5U Ceramic Capacitor		Panasonic	ECU-S1H104MEA	P4924-ND	$ 0.21	
		C22	0.1uF	0.1uF 50V Z5U Ceramic Capacitor		Panasonic	ECU-S1H104MEA	P4924-ND	$ 0.21	
		C23	0.1uF	0.1uF 50V Z5U Ceramic Capacitor		Panasonic	ECU-S1H104MEA	P4924-ND	$ 0.21	
		C24	0.1uF	0.1uF 50V Z5U Ceramic Capacitor		Panasonic	ECU-S1H104MEA	P4924-ND	$ 0.21	
		C25	0.1uF	0.1uF 50V Z5U Ceramic Capacitor		Panasonic	ECU-S1H104MEA	P4924-ND	$ 0.21	
2	8	C2	1uF	1.0uF 16V Solid Tantalum Capacitor		Panasonic	ECS-F1CE105K	P2105-ND	$ 0.24	
		C14	1uF	1.0uF 16V Solid Tantalum Capacitor		Panasonic	ECS-F1CE105K	P2105-ND	$ 0.24	
		C17	1uF	1.0uF 16V Solid Tantalum Capacitor		Panasonic	ECS-F1CE105K	P2105-ND	$ 0.24	
		C7	1uF	1.0uF 16V Solid Tantalum Capacitor		Panasonic	ECS-F1CE105K	P2105-ND	$ 0.24	
		C8	1uF	1.0uF 16V Solid Tantalum Capacitor		Panasonic	ECS-F1CE105K	P2105-ND	$ 0.24	
		C9	1uF	1.0uF 16V Solid Tantalum Capacitor		Panasonic	ECS-F1CE105K	P2105-ND	$ 0.24	
		C10	1uF	1.0uF 16V Solid Tantalum Capacitor		Panasonic	ECS-F1CE105K	P2105-ND	$ 0.24	
		C11	1uF	1.0uF 16V Solid Tantalum Capacitor		Panasonic	ECS-F1CE105K	P2105-ND	$ 0.24	
3	1	C3	0.0068uF	0.0068uF 50V X7R Ceramic Capacitor		Panasonic	ECU-S1H682KBA	P4951-ND	$ 0.18	*
4	1	C12	4.7uF	4.7uF 16V Solid Tantalum Capacitor		Panasonic	ECS-F1CE475K	P2036-ND	$ 0.39	
5	1	C13	220uF	220uF 25V Aluminum Electrolytic Cap		Panasonic	ECE-A1EU221	P6240-ND	$ 0.21	
6	2	C15	22uF	22uF 25V Aluminum Electrolytic Cap		Panasonic	ECE-A1EU220	P6236-ND	$ 0.09	
		C16	22uF	22uF 25V Aluminum Electrolytic Cap		Panasonic	ECE-A1EU220	P6236-ND	$ 0.09	
7	1	C20	33pF	33pF 100V C0G Ceramic Capacitor		Panasonic	ECU-S2A330JCA	P4843-ND	$ 0.18	
8	1	D1	1N5226B	3.3V 500mW Zener Diode	DO-35	Diodes Inc.	1N5226B	1N5226BCT-ND	$ 0.22	
9	1	D2	1N5240B	10V 500mW Zener Diode	DO-35	Diodes Inc.	1N5240B	1N5240BCT-ND	$ 0.22	
10	1	ISO1	4N36	Opto Isolator w/Photo Transistor Output	6DIP300	Quality Tech	4N36	4N36QT-ND	$ 0.40	
11	1	P1	CONN. DB9	9 Pin D-Sub Right Angle Connector		AMP	745781-4	A2100-ND	$ 1.70	
12	1	PCB1		NHRC-2 Repeater Controller PCB		NHRC	NHRC-2 PCB rev. B	N/A		**
13	1	Q1	MPF102	N-Channel JFET	TO-92	Nat'l Semi	MPF102	MPF102-ND	$ 0.74	
14	3	Q2	2N2222	NPN Transistor	TO-92	Nat'l Semi	PN2222	PN2222-ND	$ 0.32	
		Q3	2N2222	NPN Transistor	TO-92	Nat'l Semi	PN2222	PN2222-ND	$ 0.32	
		Q4	2N2222	NPN Transistor	TO-92	Nat'l Semi	PN2222	PN2222-ND	$ 0.32	
15	1	Q5	2N3906	PNP Transistor	TO-92	Nat'l Semi	2N3906	2N3906-ND	$ 0.31	
16	1	Q6	IRL530	N-Channel Logic Level MOSFET	TO-220	IRF	IRF510	IRF510-ND	$ 0.77	
17	8	R1	10K	10K 5% 1/4W Carbon Film Resistor	RN55	Yaego	10K CR-1/4W-B 5%	10KQBK-ND	$ 0.02	
		R2	10K	10K 5% 1/4W Carbon Film Resistor	RN55	Yaego	10K CR-1/4W-B 5%	10KQBK-ND	$ 0.02	
		R8	10K	10K 5% 1/4W Carbon Film Resistor	RN55	Yaego	10K CR-1/4W-B 5%	10KQBK-ND	$ 0.02	
		R15	10K	10K 5% 1/4W Carbon Film Resistor	RN55	Yaego	10K CR-1/4W-B 5%	10KQBK-ND	$ 0.02	
		R17	10K	10K 5% 1/4W Carbon Film Resistor	RN55	Yaego	10K CR-1/4W-B 5%	10KQBK-ND	$ 0.02	
		R26	10K	10K 5% 1/4W Carbon Film Resistor	RN55	Yaego	10K CR-1/4W-B 5%	10KQBK-ND	$ 0.02	
		R28	10K	10K 5% 1/4W Carbon Film Resistor	RN55	Yaego	10K CR-1/4W-B 5%	10KQBK-ND	$ 0.02	
		R31	10K	10K 5% 1/4W Carbon Film Resistor	RN55	Yaego	10K CR-1/4W-B 5%	10KQBK-ND	$ 0.02	
18	1	R3	51K	51K 5% 1/4W Carbon Film Resistor	RN55	Yaego	51K CR-1/4W-B 5%	51KQBK-ND	$ 0.02	*

NHRC-2 Repeater Controller BOM

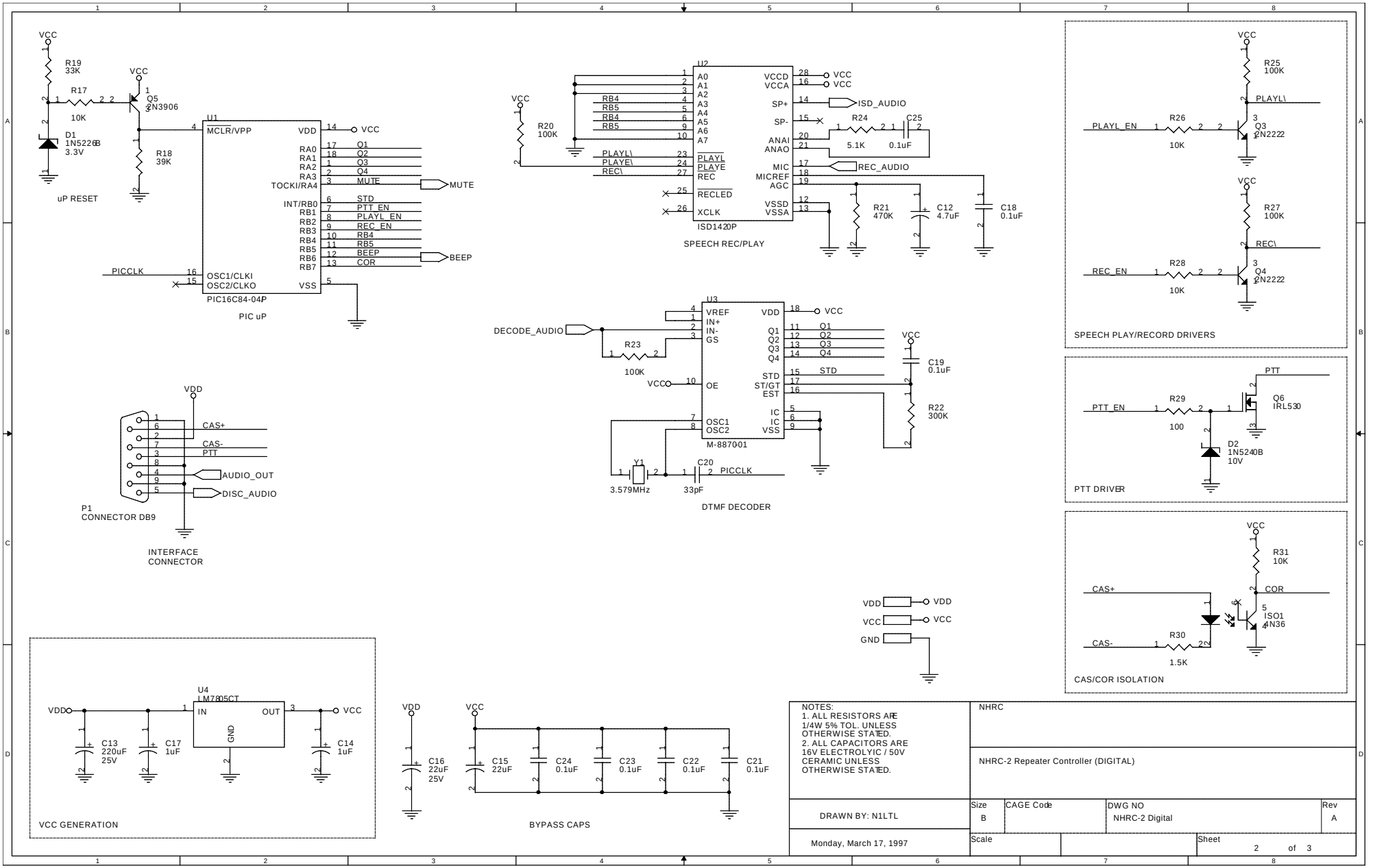
Item	Qty.	Ref.	Value	Description	Pkg.	Mfg.	Mfg. P/N	Digi-Key P/N	Unit Cost	Notes
19	1	R4	510K	510K 5% 1/4W Carbon Film Resistor	RN55	Yaego	510K CR-1/4W-B 5%	510KQBK-ND	$ 0.02	*
20	7	R5	100K	100K 5% 1/4W Carbon Film Resistor	RN55	Yaego	100K CR-1/4W-B 5%	100KQBK-ND	$ 0.02	
		R6	100K	100K 5% 1/4W Carbon Film Resistor	RN55	Yaego	100K CR-1/4W-B 5%	100KQBK-ND	$ 0.02	
		R16	100K	100K 5% 1/4W Carbon Film Resistor	RN55	Yaego	100K CR-1/4W-B 5%	100KQBK-ND	$ 0.02	
		R20	100K	100K 5% 1/4W Carbon Film Resistor	RN55	Yaego	100K CR-1/4W-B 5%	100KQBK-ND	$ 0.02	
		R23	100K	100K 5% 1/4W Carbon Film Resistor	RN55	Yaego	100K CR-1/4W-B 5%	100KQBK-ND	$ 0.02	
		R25	100K	100K 5% 1/4W Carbon Film Resistor	RN55	Yaego	100K CR-1/4W-B 5%	100KQBK-ND	$ 0.02	
		R27	100K	100K 5% 1/4W Carbon Film Resistor	RN55	Yaego	100K CR-1/4W-B 5%	100KQBK-ND	$ 0.02	
21	2	R7	1K	1K 5% 1/4W Carbon Film Resistor	RN55	Yaego	1K0 CR-1/4W-B 5%	1KQBK-ND	$ 0.02	
		R10	1K	1K 5% 1/4W Carbon Film Resistor	RN55	Yaego	1K0 CR-1/4W-B 5%	1KQBK-ND	$ 0.02	
22	4	R9	22K	22K 5% 1/4W Carbon Film Resistor	RN55	Yaego	22K CR-1/4W-B 5%	22KQBK-ND	$ 0.02	
		R12	22K	22K 5% 1/4W Carbon Film Resistor	RN55	Yaego	22K CR-1/4W-B 5%	22KQBK-ND	$ 0.02	
		R13	22K	22K 5% 1/4W Carbon Film Resistor	RN55	Yaego	22K CR-1/4W-B 5%	22KQBK-ND	$ 0.02	
		R14	22K	22K 5% 1/4W Carbon Film Resistor	RN55	Yaego	22K CR-1/4W-B 5%	22KQBK-ND	$ 0.02	
23	2	R11	33K	33K 5% 1/4W Carbon Film Resistor	RN55	Yaego	33K CR-1/4W-B 5%	33KQBK-ND	$ 0.02	
		R19	33K	33K 5% 1/4W Carbon Film Resistor	RN55	Yaego	33K CR-1/4W-B 5%	33KQBK-ND	$ 0.02	
24	1	R18	39K	39K 5% 1/4W Carbon Film Resistor	RN55	Yaego	39K CR-1/4W-B 5%	39KQBK-ND	$ 0.02	
25	1	R21	470K	470K 5% 1/4W Carbon Film Resistor	RN55	Yaego	470K CR-1/4W-B 5%	470KQBK-ND	$ 0.02	
26	1	R22	300K	300K 5% 1/4W Carbon Film Resistor	RN55	Yaego	300K CR-1/4W-B 5%	300KQBK-ND	$ 0.02	
27	1	R24	5.1K	5.1K 5% 1/4W Carbon Film Resistor	RN55	Yaego	5K1 CR-1/4W-B 5%	5.1KQBK-ND	$ 0.02	
28	1	R29	100	100 5% 1/4W Carbon Film Resistor	RN55	Yaego	100E CR-1/4W-B 5%	100QBK-ND	$ 0.02	
29	1	R30	1.5K	1.5K 5% 1/4W Carbon Film Resistor	RN55	Yaego	1K5 CR-1/4W-B 5%	1.5KQBK-ND	$ 0.02	
30	1	SKT1		8 pin DIP socket		AMP	2-640463-3	A9308-ND	$ 0.05	
31	2	SKT2		18 pin DIP socket		AMP	2-640359-3	A9318-ND	$ 0.10	
		SKT3		18 pin DIP socket		AMP	2-640359-3	A9318-ND	$ 0.10	
32	1	SKT4		28 pin DIP socket		AMP	2-640362-3	A9328-ND	$ 0.19	
33	1	SKT5		6 pin DIP socket		AMP	2-641296-3	A9306-ND	$ 0.04	
34	1	SW1	SW PB	2 Pin 0.100" Center Header		Molex	22-03-2021	WM4000-ND	$ 0.20	
35	1	U1	PIC16C84-04/P	8 Bit RISC Microcontroller	18DIP300	Microchip	PIC16C84-04/P	PIC16C84-04/P-ND	$ 6.88	**/***
36	1	U2	ISD1420P	Single-Chip Voice Record/Playback	28DIP600	ISD	ISD1420P	ISD1420P-ND	$ 8.75	**
37	1	U3	M-8870-01	DTMF Decoder	18DIP300	Holtek	HT9170	HT-9170-ND	$ 2.63	**
38	1	U4	LM7805CT	5V 1.5A Voltage Regulator	TO-220	Nat'l Semi	LM340T-5	LM340T-5.0-ND	$ 0.70	
39	1	U5	LM358	Dual Low Power Op-Amp	8DIP300	Nat'l Semi	LM358AN	LM358N-ND	$ 0.46	
40	5	VR1	10K	10K 6mm Single Turn Cermet Pot		Panasonic	EVN-36CA00B14	36C14-ND	$ 0.52	
		VR3	10K	10K 6mm Single Turn Cermet Pot		Panasonic	EVN-36CA00B14	36C14-ND	$ 0.52	
		VR4	10K	10K 6mm Single Turn Cermet Pot		Panasonic	EVN-36CA00B14	36C14-ND	$ 0.52	
		VR5	10K	10K 6mm Single Turn Cermet Pot		Panasonic	EVN-36CA00B14	36C14-ND	$ 0.52	
		VR6	10K	10K 6mm Single Turn Cermet Pot		Panasonic	EVN-36CA00B14	36C14-ND	$ 0.52	
41	1	VR2	500K	500K 6mm Single Turn Cermet Pot		Panasonic	EVN-36CA00B55	36C55-ND	$ 0.52	
42	1	Y1	3.579MHz	3.579545MHz Color Burst Crystal	HC49	CTS	MP036S	CTX049-ND	$ 1.27	

NOTES: * BOM shown is for version with optional de-emphasis circuit installed. Remove C3 and change R3 & R4 to 100K to disable de-emphasis.

** Items included with partial kit.

*** May be substitiuted with Digi-Key P/N: PIC16F84-04/P (upgraded version)

Digi-Key pricing based on Catalog Q991. Pricing may vary.



NOTES:
1. ALL RESISTORS ARE 1/4W 5% TOL. UNLESS OTHERWISE STATED.
2. ALL CAPACITORS ARE 16V ELECTROLYIC / 50V CERAMIC UNLESS OTHERWISE STATED.

NHRC

NHRC-2 Repeater Controller (DIGITAL)

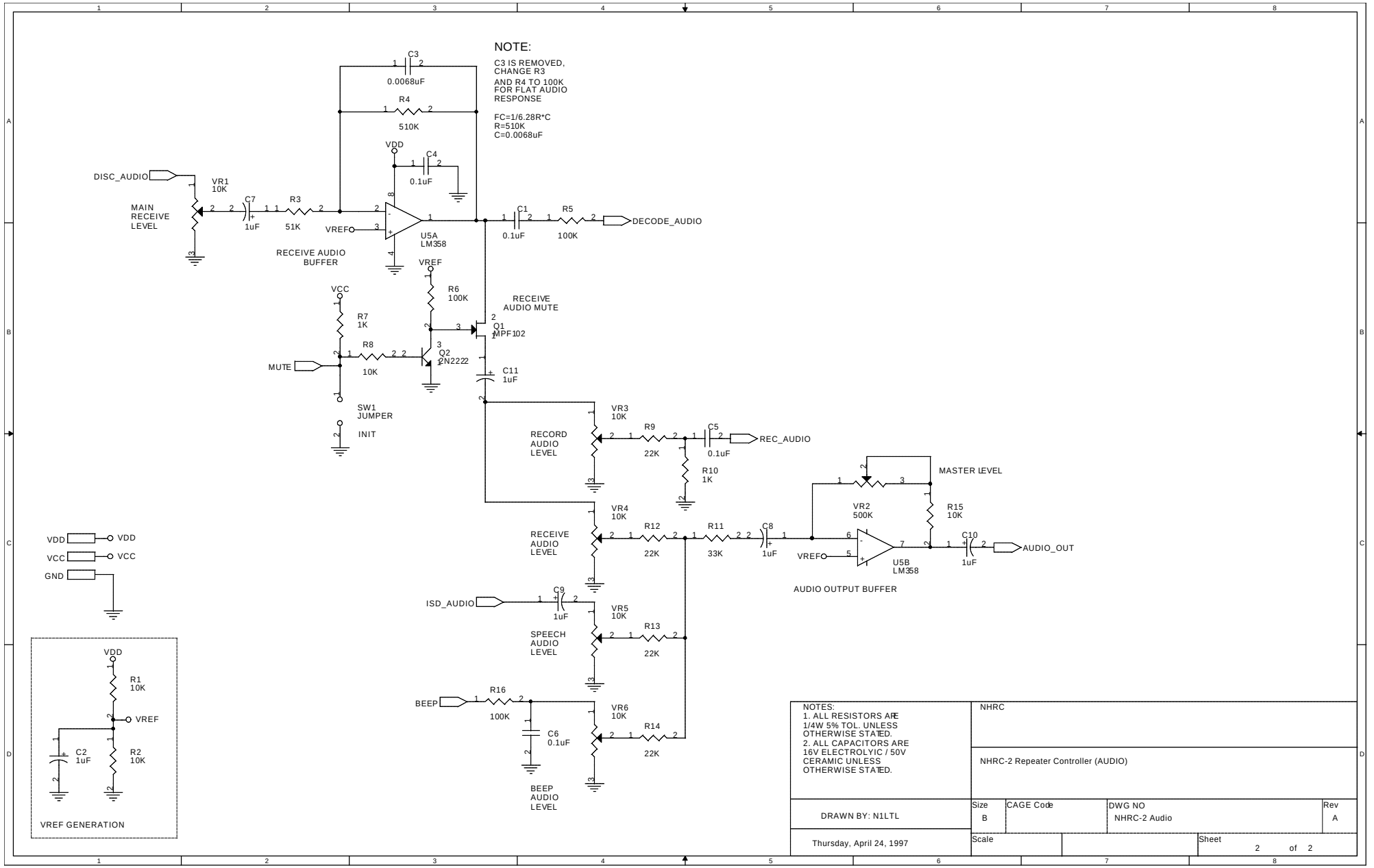
DRAWN BY: N1LTL

Monday, March 17, 1997

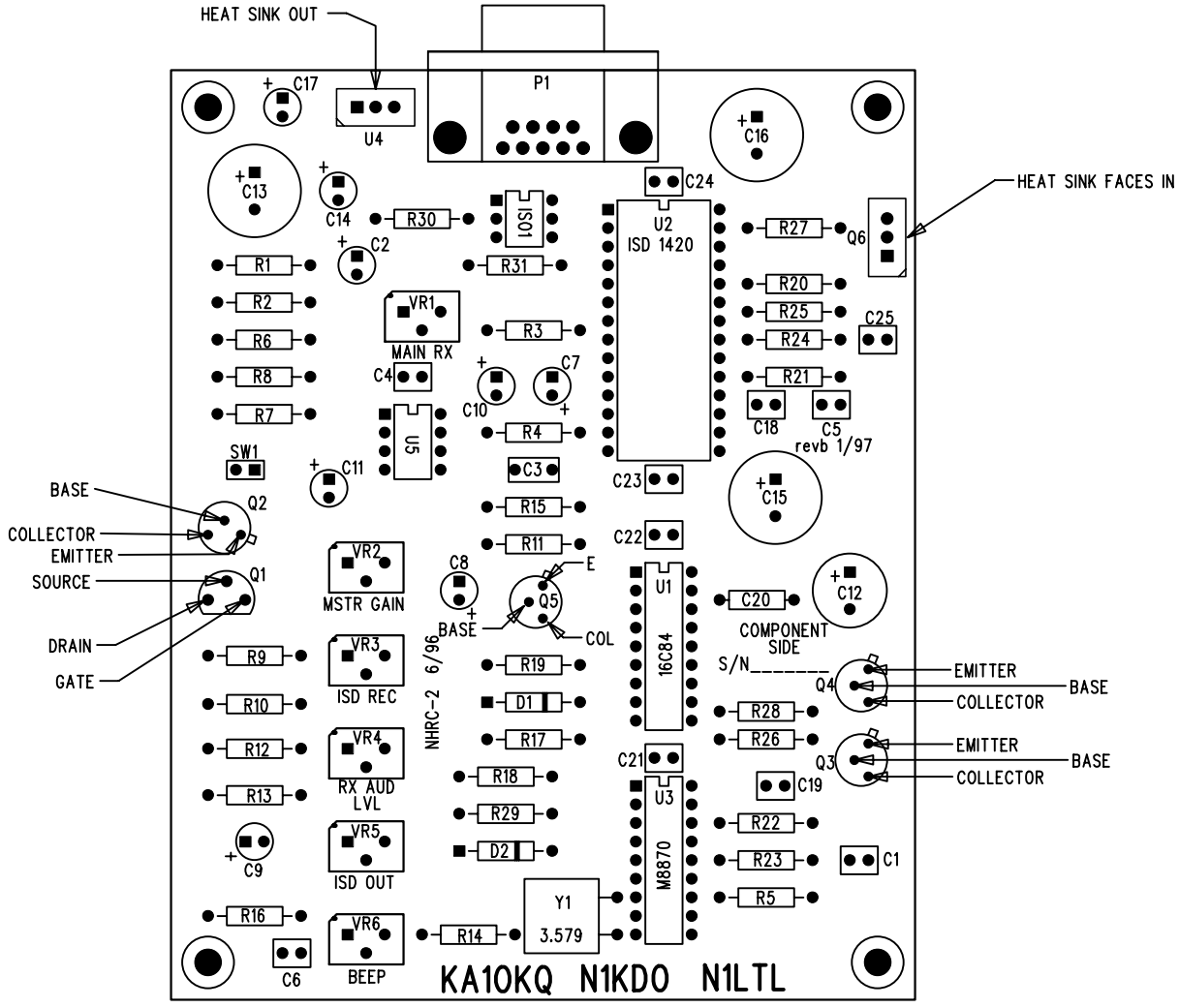
Size	CAGE Code	DWG NO	Rev
B		NHRC-2 Digital	A

Scale

Sheet 2 of 3


NOTE:
C3 IS REMOVED, CHANGE R3 AND R4 TO 100K FOR FLAT AUDIO RESPONSE
FC=1/6.28R*C
R=510K
C=0.0068uF
C3
0.0068uF
R4
510K
VDD
C4
0.1uF
DISC_AUDIO
VR1
10K
MAIN RECEIVE LEVEL
C7
1uF
R3
51K
VREF
U5A
LM358
RECEIVE AUDIO BUFFER
C1
0.1uF
R5
100K
DECODE_AUDIO
VREF
R6
100K
RECEIVE AUDIO MUTE
VCC
R7
1K
Q1
MPF102
R8
10K
Q2
2N2222
MUTE
C11
1uF
SW1
JUMPER
INIT
VR3
10K
RECORD AUDIO LEVEL
R9
22K
C5
0.1uF
REC_AUDIO
R10
1K
MASTER LEVEL
VR2
500K
R15
10K
VR4
10K
RECEIVE AUDIO LEVEL
R12
22K
R11
33K
C8
1uF
U5B
LM358
C10
1uF
AUDIO_OUT
AUDIO OUTPUT BUFFER
VDD
VCC
GND
C9
1uF
ISD_AUDIO
VR5
10K
SPEECH AUDIO LEVEL
R13
22K
R16
100K
BEEP
C6
0.1uF
VR6
10K
R14
22K
BEEP AUDIO LEVEL
VDD
R1
10K
VREF
C2
1uF
R2
10K
VREF GENERATION
NOTES:
1. ALL RESISTORS ARE 1/4W 5% TOL. UNLESS OTHERWISE STATED.
2. ALL CAPACITORS ARE 16V ELECTROLYIC / 50V CERAMIC UNLESS OTHERWISE STATED.
NHRC
NHRC-2 Repeater Controller (AUDIO)
DRAWN BY: N1LTL
Thursday, April 24, 1997
Size B
CAGE Code
DWG NO NHRC-2 Audio
Rev A
Scale
Sheet 2 of 2

SOCKET YOUR CHIPS !!!



ASSEMBLY NOTES

1. SOCKET ALL OF YOUR CHIPS !
2. PLACE TAPE UNDER CRYSTAL Y1 TO PREVENT SHORTING TO TRACES
3. U4 LM7805 HEAT SINK FACES OUT
4. Q6 IRF510 OR EQUIV HEAT SINK FACES IN
5. C7 AND C8 ONLY "+" SIGN GOES TO ROUND PAD ALL OTHERS "+" TO SQUARE PAD

TECH SUPPORT IS AVAILABLE ON OUR WEB SITE AT http://www.nhrc.net

NHRC LLC Limited Warranty

NHRC LLC warrants that it's assembled and tested products will be free from defects in materials and workmanship for a period of NINETY DAYS from the date of shipment. During this period, NHRC LLC will repair or replace, at our option, any of our products that fail as a result of defects in materials or workmanship. NHRC LLC's liability will be limited to parts, labor, and return shipping for this period.

NHRC LLC warrants that it's kit products will contain components that are free from defects in materials and workmanship for a period of THIRTY DAYS from the date of shipment. During this period, NHRC will replace any of the components in a kit ONCE. Subsequent replacement of any component any subsequent times is completely at the discretion of NHRC LLC, and may require the complete return of the kit.

In no case will NHRC LLC be liable for products damaged by improper wiring (including, but not limited to, over-voltage or application of reverse polarity), physical damage resulting from misuse and/or abuse of the product, neglect, or acts of God (lightning, floods, etc.).

Unauthorized modification of a NHRC product will void the warranty on the modified product.

In no case will NHRC LLC be liable for any direct, consequential, or incidental loss or damage resulting from the use or inability to use any of it's products.

Some states or countries do not allow the limitation of incidental or consequential damages, so the paragraph above may not apply to you.

This warranty applies only to the original purchaser of the product; proof of purchase must be presented to receive warranty service.

Mail comments to *otterson@nhrc.net*