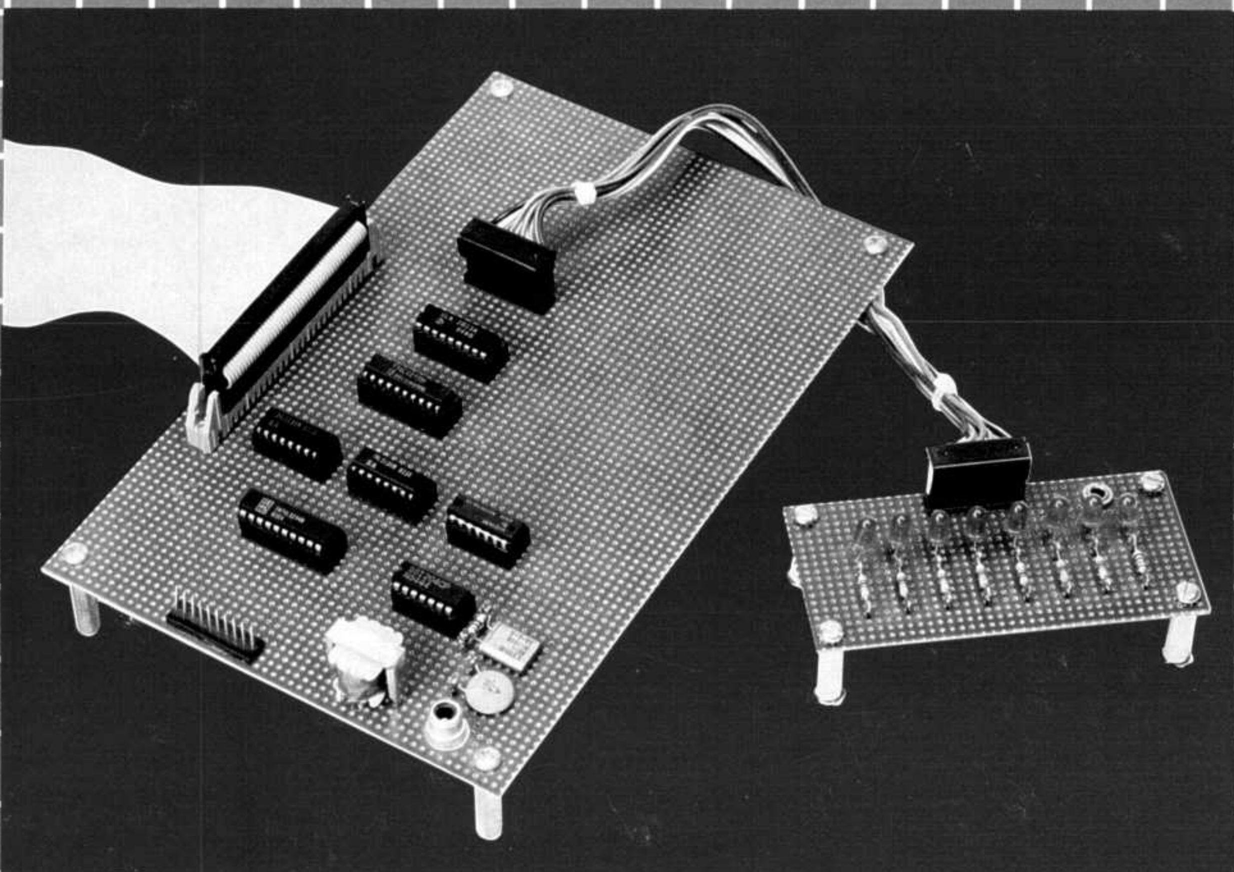
QEX 62

$1.75

APRIL 1987

ARRL Experimenters' Exchange and AMSAT Satellite Journal



QEX (ISSN: 0886-8093) is published monthly by the American Radio Relay League, Newington, CT USA.

David Sumner, K1ZZ
Publisher

Paul L. Rinaldo, W4RI
Editor

Maureen Thompson, KA1DYZ
Assistant Editor

Dr. Ron Long, W8GUS
Associate Editor

William Conwell, K2PO
Geoffrey H. Krauss, WA2GFP
Bill Olson, W3HQT
Contributing Editors

Lisa Fuini
QEX Circulation

Michelle Chrisjohn, WB1ENT
Production Supervisor

Deborah Strzeszkowski
Assistant Production Supervisor

Leslie Bartoloth
Typesetting and Layout

Sue Fagan
Graphic Design Supervisor

David Pingree
Technical Illustrator

Lee Aurick, W1SE
Advertising Manager

Sandy Gerli, AC1Y
Deputy Advertising Manager

Technical Department
Charles L. Hutchinson, K8CH
Manager
Gerald L. Hall, K1TD
Deputy Manager
Paul Pagel, N1FB, Mark Wilson, AA2Z
Senior Assistant Technical Editors
Bruce O. Williams, WA6IVC
Assistant Technical Editor

Production Department
E. Laird Campbell, W1CUT, *Manager*
Joel P. Kleinman, N1BKE, *Deputy Manager*

Circulation Department
Debra Chapor, *Manager*

Offices

225 Main St, Newington, CT 06111 USA
Telephone: 203-666-1541
Telex: 650215-5052 MCI
Electronic Mail: MCI MAIL ID:215-5052
(user name ARRL)

Subscription rate for 12 issues:
In the US by Third Class Mail:
ARRL/AMSAT Member $8, nonmember $16;
US by First Class Mail:
ARRL/AMSAT Member $13, nonmember $21;
Elsewhere by Airmail:
ARRL/AMSAT Member $23, nonmember $31.

QEX subscription orders, changes of address, and reports of missing or damaged copies may be marked: *QEX* Circulation.

Members are asked to include their membership control number or a label from their *QST* wrapper when applying.

TABLE OF CONTENTS

COLUMNS

ABOUT THE COVER

The DTMF-64² project. A six-digit code enables the software to perform a variety of tasks from a local or remote mode.

THE AMERICAN RADIO RELAY LEAGUE, INC

The American Radio Relay League, Inc, is a noncommercial association of radio amateurs, organized for the promotion of interest in Amateur Radio communication and experimentation, for the establishment of networks to provide communications in the event of disasters or other emergencies, for the advancement of the radio art and of the public welfare, for the representation of the radio amateur in legislative matters, and for the maintenance of fraternalism and a high standard of conduct.

ARRL is an incorporated association without capital stock chartered under the laws of the State of Connecticut, and is an exempt organization under Section 501(c)(3) of the Internal Revenue Code of 1954. Its affairs are governed by a Board of Directors, whose voting members are elected every two years by the general membership. The officers are elected or appointed by the Directors. The League is noncommercial, and no one who could gain financially from the shaping of its affairs is eligible for membership on its Board.

"Of, by, and for the radio amateur," ARRL numbers within its ranks the vast majority of active amateurs in the nation and has a proud history of achievement as the standard-bearer in amateur affairs. As its membership journal, ARRL publishes *QST* monthly.

A bona fide interest in Amateur Radio is the only essential qualification of membership; an Amateur Radio license is not a prerequisite, although full voting membership is granted only to licensed amateurs in the US and Canada.

Officers
President: LARRY E. PRICE, W4RA
PO Box 2067, Statesboro, GA 30458
Executive Vice President: DAVID SUMNER, K1ZZ

AMSAT®
RADIO AMATEUR SATELLITE CORP

President: VERN "RIP" RIPORTELLA, WA2LQQ

Purposes of *QEX*:

1) provide a medium for the exchange of ideas and information between Amateur Radio experimenters
2) document advanced technical work in the Amateur Radio Field
3) support efforts to advance the state of the Amateur Radio art.

All correspondence concerning *QEX* should be addressed to the American Radio Relay League, 225 Main Street, Newington, CT USA 06111. Envelopes containing manuscripts and correspondence for publication in *QEX* should be marked: Editor, *QEX*.

Both theoretical and practical technical articles are welcomed. Manuscripts should be typed and double spaced. Please use the standard ARRL abbreviations found in the 1985 and 1986 ARRL Handbooks and in the January 1984 issue of *QST*. Photos should be glossy, black-and-white positive prints of good definition and contrast, and should be the same size or larger than the size that is to appear in *QEX*.

Any opinions expressed in *QEX* are those of the authors, not necessarily those of the editor or the League. While we attempt to ensure that all articles are technically valid, authors are expected to defend their own material. Products mentioned in the text are included for your information; no endorsement is implied. The information is believed to be correct, but readers are cautioned to verify availability of the product before sending money to the vendor.

Empirically Speaking...

On Hatching Incubators

Despite some handwringing to the contrary, there is a healthy amount of experimentation going on in the Amateur Radio Service. At the same time, there is less home-brewing and lots of appliance operating going around. Isn't that a contradiction? Not really. These are opposite ends of the equipment-creation process. The appliance operator is undoubtedly pleased with the latest box with megabells and whistles for about the price of 100 pizzas. At the other end, one experimenter is happily designing an antenna entirely in software while another is burning ROMs for a frequency-hopping power supply. The problem is the discontinuity between these ends of the process. Somehow, the output of the experimenter needs to get into the hands of a practical designer, then a producer of pilot models, then a manufacturer, then a dealer, before the appliance operator can buy it. It's largely a serial process that can break down if one of its links is missing.

There has been excellent continuity in the development of amateur packet radio. The torch was carried from hams in Montreal to Vancouver to San Francisco, Washington DC and Tucson to US (and now some Japanese) manufacturers to hams all over the world and to other radio services enjoying the fruits of these labors. The amateur satellite program has benefited from similar development patterns. Key to these success stories have been innovation, leadership, and networking—often on an international scale.

The technique of one experimenter completing a project, publishing it, and home-brewers reproducing it in onesies is mostly a memory. Once the engineering model works, the experimenter jumps to a new project... maybe knows that it takes drudgery to make it reproducible... maybe can't write or gets no pleasure from doing the documentation... certainly doesn't want to market it... Nirvana for the innovator is the gleam, the contemplation, the chase, the catch, and on to the next gleam.

What's missing is the part that the pure experimenter doesn't want to do. Probably the engineering model is a maze of clip leads, one-of-a-kind chips and unannotated code written in VaporDOS. Who is going to productize it, document it and make it available to earth men?

There are *centers of excellence* (COEs) in the US and elsewhere where these things happen. But, the existing COEs could use a boost and some potential ones a jump start. A model for potential COEs might be an area with high-tech industry/government/academia, some Amateur Radio experimenters, and some hams that can supply the leadership and other resources. If you live in a metropolitan area of any size, doesn't that model fit your location? If there are bearded experimenters cooking up some neat stuff in their basement caldrons near you, why not see what a little teamwork could produce?

Throughout the land, there are businesses called *incubators*. The idea is to provide an office environment replete with a receptionist, word processors, photocopiers and the like for the individual whose business is not large enough to own all these services. Why not Amateur Radio experimenters' incubators? Old El Beardo just likes to innovate. Maria D. Plume is a whiz at the PC. Then there's Ungar who can solder anything, and Attila with the management talent. All we need now is to pick which pizza parlor to use as our conference room and a 2-meter frequency for intercom. Hey, we got us an incubator!

Amateur Radio experimental incubators have been working in a number of towns. Each seems to have its own culture. What they seem to have in common is some neural activity, a shared goal or two, some energy, and an environment conducive to creativity.

QEX will welcome articles on Amateur Radio incubators that have somehow caught on and correspondence from those who may need help on starting a new one.—W4RI

Correspondence

Satellite Ethics Questioned

In his article on the Phase 3C Mode-S transponder (Oct 1986 *QEX*, p 10), W. D. McCaa, Jr, KØRZ, suggests that the ground station receiver could use AFC to overcome frequency drift and Doppler effects. Would this not violate the good-operating-practice dictum on satellites which states that the transmitter frequency should be changed to maintain a constant downlink frequency at the receiver? If a servo system of any kind is to be used, it would appear preferable to close the loop onto the transmitter rather than onto the receiver.—*Alec H. B. Walker, KJ4IW, 6290 Manasota Key Rd, Englewood, FL 33533*

Red Ryder Returns To The Airwaves

After reading about Dave Borden's, K8MMO, PACANSWR program (Dec 1986 *QEX*, p 12), I would like to tell other readers about Red Ryder software as a possible packet answer machine for the Apple® Macintosh computer. Red Ryder is a user-supported asynchronous modem communications program distributed by the Freesoft Co.

I have been using version 9.2 of the Red Ryder program with a 512-kbyte Macintosh and the Kantronics KPC-2 TNC. Interaction with the calling station is done through easily understandable menus. The program is a reasonable packet answering machine, capable of sending a message to anyone interested, and will receive incoming mail. Contact The Freesoft Company, 10828 Lacklink, St Louis, MO 63114 for more information about obtaining a copy.—*Daniel Rosenne, 4X4SK, PO Box 21009, Tel Aviv 61 210, Israel*

1987 Orbital Predictions Available

Project OSCAR, Inc is preparing 1987 orbital predictions for all presently available Amateur Radio satellites. The predictions include UTC times and longitude for all south to north equatorial crossings of the two active Russian satellites carrying Mode-A transponders (RS5 and RS7), the two UoSAT scientific satellites (O9 and O11), and for JAS-1 (FO12).

When this data is used with an appropriate plotter, the user can determine satellite access times. To get your copy of the 1987 orbital prediction calendar, any satellite user living in the US, Canada or Mexico should send $10 ($12 for all overseas destinations) to Project OSCAR, Inc, PO Box 1136, Los Altos, CA 94023-1136.—*Tnx John Pronko, W6XN*

Overcoming Fundamental Overload

The article, "High-Pass Filters to Combat TVI," by Dick Jansson, WD4FAB, and Ed Wetherhold, W3NQN (Feb 1987 *QEX*, p 7), was a good textbook treatment of the subject. In the field, there is a problem of "fundamental overload." This is where the outside shield of the incoming cable acts as an antenna, especially to the usual ungrounded or poorly grounded set. This RF, of course, passes around any TVI filter.

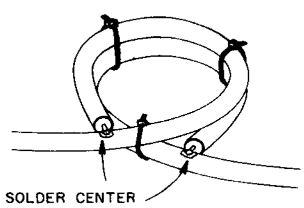


Fig 1—Overcoming fundamental overload. An explanation is given in the text.

One solution is the closely-coupled shield loops as shown in Fig 1. Cut the incoming cable about a foot from the set and form the loops. This is a simple, effective filter method and the price is right! I learned this trick several years ago from Gerald W. Dale, ZS6AUB.—*Wayne W. Cooper, AG4R, 9302 NW 2nd Place, Miami Shores, FL 33150*

Who's Using Biphase Digital Communications Systems for Emergency Purposes?

Many amateurs have been experimenting with biphase digital communications systems since the use of this method became available on OSCAR 10 and Fuji 12. I am especially interested in comparing notes with others who have constructed *simple* decoders and attempted slower baud rates and reduced bandwidths. The purpose here is to use the "experimenters' band" (160-190 kHz), as well as to investigate the possibility of a slow communications method possibly for people under emergency conditions via a simple keyboard. Has anyone been involved in such an effort?—*Cliff Buttschardt, W6HDO, 950 Pacific St, Morro Bay, CA 93442*

Antenna Impedance Measurement Results

Thank you for publishing my letter in the Correspondence column (Jan '87 *QEX*, p 3) regarding my failed attempts at antenna impedance measurement. I consider *QEX* a true experimenters' journal. Here are some excerpts from the mail I received as a result of my letter's publication.

I received many explanations, *all* of which have merit. One such explanation is if I were exciting the antenna with my own signal source, the antenna is still receiving radiated signals from other sources. These received signals would indicate false nulls or dips during the measuring process.

Another letter explained that the resistor and capacitor used during the nulling process will have different values at RF than they would at audio or dc. One example stated that a 1-kΩ resistor appears as 300 and 600 Ω at RF because of packaging capacitance, lead inductance and the material used to form the resistance. Yet another explanation reinforced my own suspicion that my measuring equipment was loading down the circuit being tested.

By far the most intriguing account was one that I never considered—a signal generator is not a perfect voltage source. It doesn't have zero internal impedance, nor does it produce a constant voltage output when driving a variety of loads. To fully appreciate this statement, I drew a circuit including an "imperfect" signal generator driving the circuit to be measured with my test elements inserted. Again, thank you *QEX*.—*Clifford J. Appel, WB6AWM/7, PO Box 241, Electric City, WA 99123.*

The DTMF-64² Decoder

By Ronald P. Kumetz, Jr, N2ENW
PO Box 24
Elmwood Park, NJ 07407

After I made several attempts to design hardware-based controllers for dual-tone, multifrequency (DTMF) paging, home-appliance control, remote base and repeater control, it became apparent that each of these tasks could be accomplished more efficiently and reliably using a microprocessor-based system. Since the design of a dedicated microprocessor-based device from scratch requires an expensive development system, the use of an inexpensive personal computer is a logical alternative. The Commodore 64® has more than enough computing power to accomplish the job, and it is inexpensive and readily available.

In choosing a computer to serve as the controller's brain, the need for external hardware is minimal. Almost all of the information processing is done by the program. And, customization of the controller through simple software modifications is advantageous. The software is written in BASIC and is fast enough to perform the assignments. Simply type in the program—no more cutting, soldering and perspiring!

Modes of Operation

In this project, the controller board is connected to a PC board consisting of eight LEDs (0 through 7). The LEDs temporarily take the place of the controlled device. The light pattern of the LEDs depends on the function code received from the controller. The function code may be entered into the controller using two modes of operation—local and remote. In the local mode, any function is turned on or off directly from a computer keyboard, whereas in the remote mode, a 12- or 16-digit keypad initializes the controller with a six-digit DTMF code received from the audio input.

The Function Code

A six-digit function code activates the controller board and LED display. The first three digits are a user-selectable security code. The security code is set while operating in the local mode and determines what characters are used to initiate a function. If the security code is not set once the program is run, the code should be checked; the computer *chooses digits at random if DIP switches* are not used.

The fourth digit is either a * (on), 0

Table 1

The DTMF-64² Decoder Program in BASIC

The software initializes a 1-minute time delay when an incorrect security code is entered via a keypad. This time delay may be reduced to 15 seconds if desired. Just change the following program statements for where the number 3600 is listed: lines 1520, 2050, 2160, 2180 and 3020. Change the 1 MIN. in line 3000 to 15 seconds and the WAIT 1 MIN. in line 3020 to wait 15 seconds.

C64 BASIC allows the programmer to abbreviate most keywords. Many of the abbreviations appear as a graphics symbol on screen. Note that any information contained in curly brackets in Table 1 are these translated symbols.

```
10 TT=56832:DIM P(7),RY(7,7),I(6),Y(6),Y$(3),S$(15)
20 S$(0)="D":S$(1)="1":S$(2)="2":S$(3)="3":S$(4)="4":S$(5)="5":S$(6)="6"
30 S$(7)="7":S$(8)="8":S$(9)="9":S$(10)="0":S$(11)="*":S$(12)="#":S$(13)="A"
40 S$(14)="B":S$(15)="C"
50 FOR X=0 TO 7:P(X)=0:FOR Y=0 TO 7:RY(X,Y)=0:NEXT Y:NEXT X
80 GOSUB 1400
90 PRINT"{WHT}":GOSUB 2000
100 REM MENU
110 PRINT"{CLR}{WHT}{C/DN}{C/DN}",TAB(14)"DTMF-64↑2"
120 PRINT TAB(15)"{C/DN}REV 2.0"
130 PRINT TAB(12)"{C/DN}N2ENW   6/85"
140 PRINT"{C/DN}{C/DN}{C/DN}SELECT DESIRED OPERATION"
150 PRINT"{C/DN}ENTER: 1  REMOTE MODE"
160 PRINT"        2  SET/RESET A DEVICE"
170 PRINT"        3  SET TIME"
180 PRINT"        4  CHECK TIME"
190 PRINT"        5  SET SECURITY CODE
200 GET N:IF N<1 OR N>5 GOTO 200
210 ON N GOSUB 2000,400,300,330,1010
220 GOTO 100
230 END
300 REM SET TIME "STIME"
310 PRINT"{CLR}"
320 PRINT"{CLR}":INPUT"ENTER TIME:HHMMSS [RETURN]";T$:TI$=T$
330 REM CHECK TIME "CTIME"
340 PRINT"{CLR}THE TIME IS:",TI$
350 FOR X=0 TO 1000:NEXT X:RETURN
400 REM LOCAL
410 PRINT"{CLR}{C/DN}ENTER DEVICE # [RETURN]":INPUT D
420 I(5)=INT(D/10):I(6)=D-(10*(I(5)))
430 IF I(5)<0 OR I(5)>7 GOTO 410
440 IF I(6)<0 OR I(6)>7 GOTO 410
450 GOSUB 600
460 IF W=0 GOTO 480
470 PRINT"{CLR}{C/DN}DEVICE",D,"IS ON":GOTO 490
480 PRINT"{CLR}{C/DN}DEVICE",D,"IS OFF"
490 PRINT"{C/DN}ENTER:  1 ON"
500 PRINT"          2 OFF"
510 PRINT"          3 MOMENTARY ON"
520 PRINT"          4 CHECK A NEW DEVICE"
530 PRINT"          5 RETURN TO MAIN MENU"
540 GET J:IF J<1 OR J>5 GOTO 540
550 ON J GOSUB 700,800,900,400,100
560 GOTO 450
570 RETURN
600 REM DCHECK
610 IF (RY((I(5)),(I(6))))=1 GOTO 630
620 W=0:GOTO 640
630 W=1
640 PT=TT+16*I(5)
650 RETURN
700 REM DON
710 IF W=1 GOTO 730
720 RY(I(5),I(6))=1:P(I(5))=P(I(5))+2↑I(6):POKE PT,P(I(5))
730 RETURN
800 REM DOF
810 IF W=0 GOTO 830
820 RY(I(5),I(6))=0:P(I(5))=P(I(5))-2↑I(6):POKE PT,P(I(5))
830 RETURN
900 REM MOM
910 IF W=1 GOTO 960
920 GOSUB 700
930 T=TI:GOSUB 600
```

Table 1

continued from previous page

```
940 IF TI-T<45 GOTO 940
950 GOSUB 800
960 RETURN
1000 REM CODE
1010 PRINT"{CLR}{C/DN}THE SECURITY CODE IS:","{C/DN}"
1020 PRINT S$(Y(1)).S$(Y(2)),S$(Y(3))
1040 PRINT"CHANGE CODE?"
1050 INPUT"Y/N [RETURN]";G$:IF G$<>"Y" GOTO 100
1060 PRINT"{CLR}{C/DN}ENTER: #1,#2,#3  [RETURN]","{C/DN}"
1070 INPUT Y$(1),Y$(2),Y$(3)
1080 GOSUB 1200
1120 PRINT"{CLR}THE NEW CODE IS:","{C/DN}"
1130 PRINT S$(Y(1)).S$(Y(2)),S$(Y(3))
1140 T=TI
1150 IF TI-T<150 GOTO 1150
1160 RETURN
1200 REM Y$ TO Y CONVERSION
1201 FOR X=1 TO 3
1202 IF VAL(Y$(X))<1 OR VAL(Y$(X))>9 GOTO 1204
1203 Y(X)=VAL(Y$(X)):GOTO 1230
1204 IF Y$(X)="0" THEN Y(X)=10:GOTO 1230
1205 IF Y$(X)="*" THEN Y(X)=11:GOTO 1230
1206 IF Y$(X)="#" THEN Y(X)=12:GOTO 1230
1207 IF Y$(X)="A" THEN Y(X)=13:GOTO 1230
1208 IF Y$(X)="B" THEN Y(X)=14:GOTO 1230
1209 IF Y$(X)="C" THEN Y(X)=15:GOTO 1230
1210 IF Y$(X)="D" THEN Y(X)=0:GOTO 1230
1220 GOTO 1240
1230 NEXT X
1240 RETURN
1400 REM READ SWITCHES
1410 S1=PEEK(TT+16):S2=PEEK(TT+32)
1420 Y(1)=INT(S1/16):Y(2)=S1-(16*(Y(1)))
1430 Y(3)=INT(S2/16):U=S2-(16*(Y(3)))
1440 RETURN
1500 REM DELAY
1510 T=TI
1520 IF TI-T<3600 GOTO 2520
1530 GOTO 2020
2000 REM REMOTE
2010 PRINT"{CLR}{C/DN}{C/DN}",TAB(10)"REMOTE MODE{C/DN}{C/DN}",TAB(43)"PRESS
2011 ANY KEY TO RETURN TO MENU"
2020 FOR Z=1 TO 3
2030 X=PEEK(TT):GETA$:IF A$ <> "" GOTO 2410
2040 IF Z=1 THEN T=TI
2050 IF TI-T>3600 GOTO 2020
2060 IF X<16 GOTO 2030
2070 I(Z)=X-16
2080 REM WE NOW HAVE A VALID DIGIT
2090 REM (-16) GETS RID OF DV
2100 REM NOW WAIT FOR INTERDIGIT PAUSE
2110 X=PEEK(TT):IF X>15 GOTO 2110
2120 NEXT Z
2130 REM NOW SEE IF SECURITY CODE IS OK
2140 FOR Z=1 TO 3
2150 IF I(Z)<>Y(Z) THEN GOSUB 3000
2160 IF TI-T>3600 GOTO 2390
2170 FOR Z=4 TO 6
2175 GET A$:IF A$ <> "" GOTO 2410
2180 X=PEEK(TT):IF TI-T>3600 GOTO 2390
2190 IF X<16 GOTO 2175
2200 REM NOW WAIT FOR PAUSE AGAIN
2205 I(Z)=X-16
2210 X=PEEK(TT):IF X>15 GOTO 2210
2220 NEXT Z
2230 REM PROCESS THE INSTRUCTION
2240 IF I(5)<1 OR I(5)>10 GOTO 2390
2250 IF I(6)<1 OR I(6)>10 GOTO 2390
2260 IF I(5)=10 THEN I(5)=0
2270 IF I(6)=10 THEN I(6)=0
2280 IF I(4)<>11 GOTO 2320
2290 GOSUB 600
2300 GOSUB 700
2310 GOTO 2390
2320 IF I(4)<>12 GOTO 2360
2330 GOSUB 600
2340 GOSUB 800
2350 GOTO 2390
2360 IF I(4)<>10 GOTO 2390
2370 GOSUB 600
2380 GOSUB 900
2390 IF RY(7,7)=0 GOTO 2000
2400 T=TI:GOTO 2170
2410 RETURN
3000 REM INVALID CODE DELAY (1 MIN.)
3010 T=TI:PRINT"{C/DN}{C/DN}"TAB(3)"INCORRECT CODE - WAIT 1 MIN."
3020 IF TI-T<3600 GOTO 3020
3040 RETURN
```

(momentarily on) or # (off). The succeeding two digits of the command is the output port number and function number of the LED to be turned on or off. The values chosen must be between 0 to 7, inclusive.

Here is an example of initializing a function. Let's say our security code is set to 3, 6, 7 and we wish to turn on function 5 of output port 0. A DTMF sequence of 3-6-7-*-0-5 is entered. Similarly, to turn off the same function, enter 3-6-7-#-0-5. The system allows you approximately 60 seconds to enter a complete sequence before the timer is reset and it begins to look for the security code again. Additionally, turning on function 77 disables the security code by eliminating the first three digits; likewise, turning off function 77 reenables the security code.

Circuit Construction

Fig 1 shows the schematic of the DTMF-64² decoder. The audio input is coupled to U1, a DTMF decoder chip. This IC converts received DTMF digits into a binary code that can be understood by the computer. When the computer is ready to accept a digit, it allows this code to pass through the buffer (U2) onto its data bus (D0-D7) where it is processed by the DTMF-64² decoder software. Fig 2 shows the expansion port pin outs if a VIC-20 computer is used instead of a C64.

The two DIP switches in the circuit enables the user to set the security code once and have the C64 read it each time the program runs. Not having the switches in the circuit results only in the computer choosing arbitrary values for the first three digits of the function code; the code can be set manually. Fig 3 shows how the switches are configured to set each code digit.

The first three digits are configured in the BCD (binary coded decimal) number system (decimal numbers 0 through 9 are represented by 4-bit binary patterns). In addition, a single digit (called "U" in the software), can be used when modifying the program to select characters other than those specified.

Circuit Operation

When a valid sequence of digits is received by the computer, it places the information onto the data bus. This information is then latched into the appropriate output port (U7-U10 and U15-U18). The output of the output driver chip is grounded for each function that turns on. The combined current sinking capacity of the eight outputs of each of the ULN2803 output drivers is 500 mA. These output drivers may be used to drive relays, optoisolators, LEDs, or just about any low-voltage device which can be activated by grounding. The output drivers also contain transient suppression diodes to

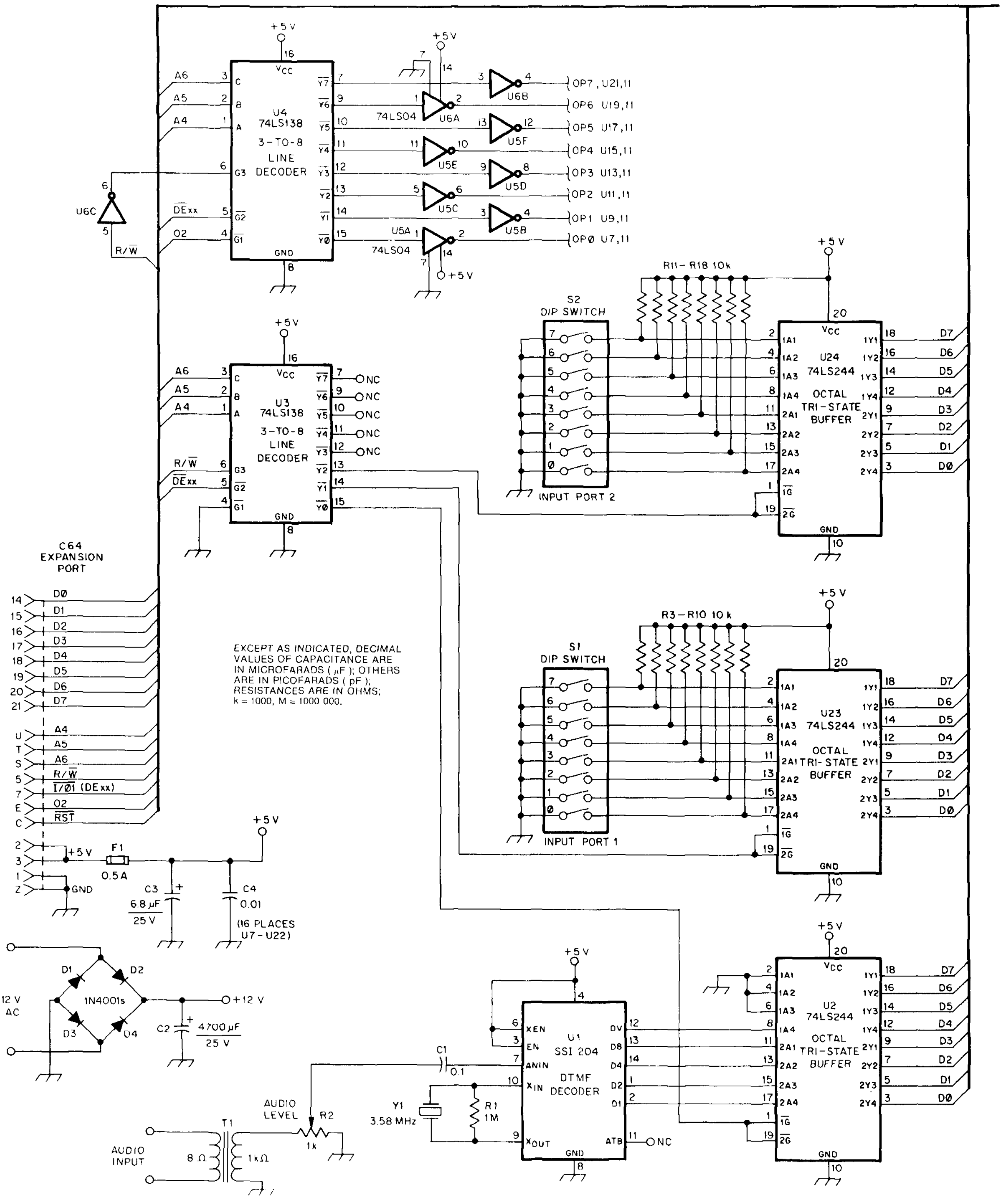
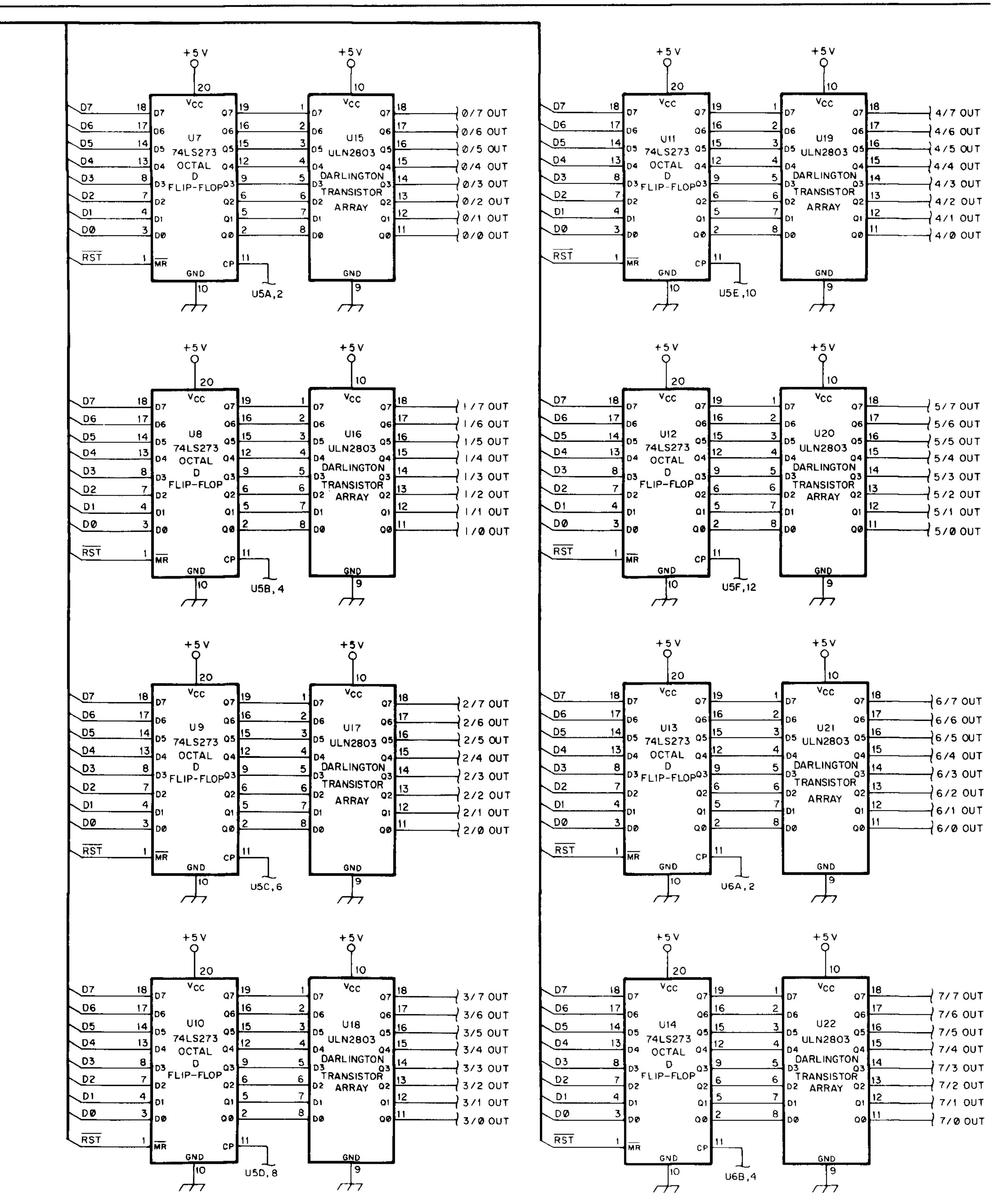


Fig 1—The DTMF-64² decoder schematic. If the circuit is used to enable many functions, the transformer must have the capacity to supply 500 mA. A fuse with an appropriate current rating should be placed in the 12-V line after the transformer.

MT1—Power transformer, pri, 117 V ac, sec, 12 V at 2A.
U1—SSI-204, dual-tone, multi-frequency decoder.
U2, U23, U24—74LS244, octal TRI-STATE® buffer.
U3, U4—74LS138, 3-to-8 line decoder.
U5, U6—74LS04, hex inverter.
U7-U14—74LS273, octal D flip-flop.



U15-U22—ULN2803, darlington transistor array.
Y1—3.58-MHz crystal.
All parts may be ordered from Jameco Electronics, 1355 Shoreway Rd, Belmont, CA 94002, tel 415-592-8097, or Circuit Specialists, PO Box 3047, Scottsdale, AZ 85257, tel 1-800-528-1417.

protect them when they are used to drive relays or other inductive loads.

The Software

The BASIC program is listed in Table 1 and has two menus. The first menu offers you a choice of the remote or local modes. Keep in mind that if DIP switches are not used in your circuit, the computer arbitrarily chooses the first three digits of the security code. Therefore, before any commands are given, it is important that the security code be checked.

The second menu is the local mode. Here you can manually set or reset a device, set or check the time or the security code. The DTMF-64² decoder software prompts the user for all local mode commands.

In the remote mode, the program waits to receive three DTMF digits. These digits are compared to the security code. If they do not match, the program looks for the security code again after the 1-minute time delay. Once the code is correctly entered, the program accepts the *, 0 or # key, the number of the output port and the function number. The software processes the desired function and waits for the next command. If you fail to complete the six-digit sequence within 60 seconds of the first digit, the timer resets to the beginning of the remote sequence and the controller again looks for the security code. (This software is provided mainly as a base for your own creative impulses.)

The Possibilities

The DTMF-64² decoder has the potential to perform many other assignments. In its present form, it makes a great controller for a remote base, a home controller, or use it to turn on a speaker when a friend is calling. Tired of losing that remote garage-door opener? Why not use the 64² to open the garage door or turn on the porch lights from the mobile or hand held? The great thing about the 64² is that it has enough functions to do many of these tasks at once.

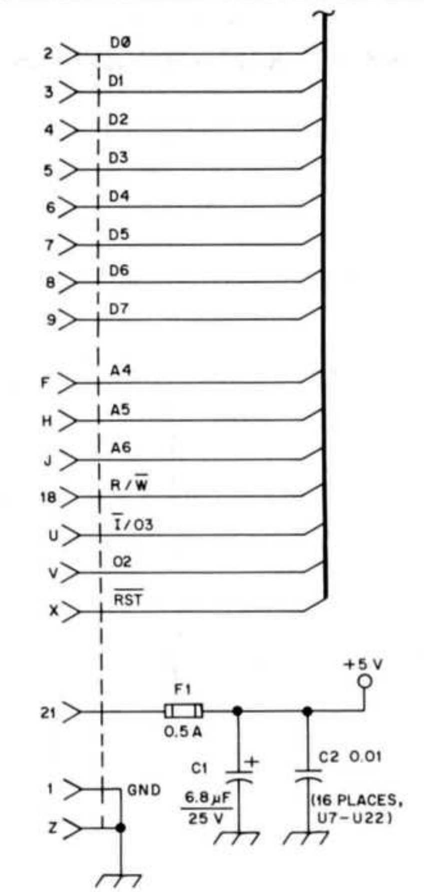


Fig 2—The VIC-20 expansion port.

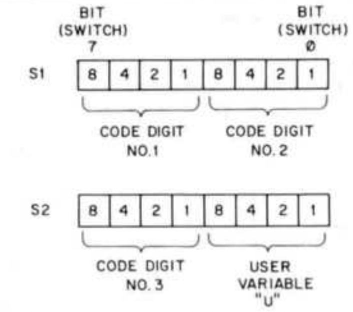


Fig 3—The first three digits of the security code are in the BCD number system. If DIP switches are used, they must be configured as shown. A user variable is available for use with software modifications.

Many other functions can be added to the controller through software modifications. Multiple security codes, interlocking functions (similar to the push- button tuning found on auto radios), and remotely alterable security codes are just some of the possibilities. When the security code is disabled, the 64² even makes a fine remote control for a model railroad or other hobby project.

To allow the 64² to function as a repeater controller, burn the software into an EPROM and use the C64's auto-start feature to power up the computer after a power loss in the DTMF-64² decoder mode. This requires no operator intervention.

The possibilities for using the DTMF-64² decoder are limited only by your imagination. Its simplicity and low cost make it a great weekend project. The 64² is not only fun, but a useful peripheral for the computer you already have or just needed one more reason to purchase.

Bits

The Diconix InkJet Printer

In the early days when computer equipment was bulky, portability was the last feature considered. However, in today's fast-paced society everything moves, including people. Many jobs are no longer performed behind the desk, but behind the wheel. It is with these types in mind that Diconix, a subsidiary of Kodak, developed a portable printer.

The Diconix 150 weighs approximately four pounds and measures 2 × 6 1/2 × 10 3/4 inches. The printer is operated by using an ac adapter or by implanting five NiCd batteries in the platen to get up to 2 hours of portable use.

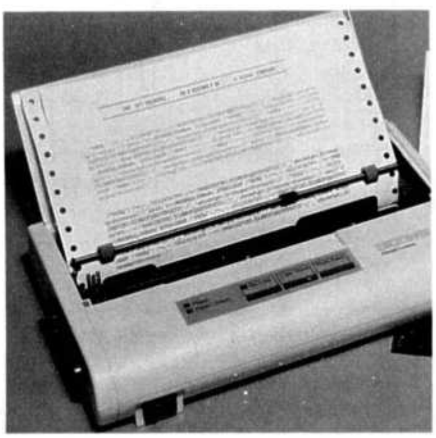
Diconix manufactures both a serial and parallel version; both use IBM and Epson command sets. Five modes of operation are accessible. Print speeds vary from 21 to 240 characters per second, depending on the type desired.

The inkjet printer cartridge for the model 150 is available in a variety of colors. Using an ink cartridge is no different than using a ribbon; pop out and replace the cartridge when the ink has been depleted.

Special coated paper accompanies the model 150. It is not necessary to purchase and use the coated paper, but it does provide consistency among the printed characters. Standard paper tends to absorb more of the ink, resulting in copy similar to that of a dot-matrix printer.

What distinguishes the model 150 from other available printers? This printer is a low-cost inkjet printer—others cost as much as $1,000. Amateur Radio operators are beginning to take packet radio on the road for fun and emergency purposes; this printer is compatible to such a setup. The model 150 is quiet, fast and portable. It is worthy of being considered for mobile use. Besides generating messages, envelopes and work using the graphics mode (WEFAX pictures) may be generated.

The Diconix model 150 printer package comes with an inkjet print head, an ac adapter/recharger, a well-written and informative operator manual and a sample package of paper. The complete package sells for $479; inkjet print heads cost $9.95. The coated paper can be purchased at any computer outlet. Look for the Diconix booth at the 1987 Dayton Hamvention, April 24-26.—*Maureen Thompson, KA1DYZ, Assistant Editor, QEX*



Pocket-sized Audio Frequency Counter

By Mark N. Richey, WA7UGB
PO Box 1082
Stanwood, WA 98292

Have you ever wanted to accurately adjust your PL™ tone? How about setting a clock oscillator output? Tune your electric organ? This small counter was designed for battery operation and is easily assembled using readily-available parts. It is a portable, accurate and inexpensive way of checking audio frequencies under 100 kHz.

The counter circuit described in this article can be built in one weekend. The counter's accuracy below 10 kHz is limited by the specifications of the crystal used. Audio-type applications are unlimited.

What led to my design of a pocket-sized audio frequency counter? My job involves on-site calibration of instruments operating at audio frequencies. Generally, I climb ladders and hang onto things with one hand. Power is not always available in these out-of-the way places, so the equipment I use must have a self-contained power source.

My counter uses CMOS logic, thus it draws less than 80 mA. This is still too great a current requirement for long periods of operation on standard batteries, so I used Nickel-Cadmium (NiCd) batteries to make the unit rechargeable. (The NiCd charger can be used to restore other batteries if the component values shown in Fig 1 are changed to reflect the voltage and current rating of the battery being charged. Charge-component values can be found under current sources in a linear-applications handbook.[1,2,3]) The counter can also be used with an external 12-30 V ac or dc source. If you are going to use the counter solely at your work bench, an ac-only power supply can be used.

Circuit Description

The counter uses a number of functional blocks that are derived from other applications. U1 is a CMOS oscillator chip that provides a 60-Hz digital clock time base. The divider and buffer circuitry (U2 and U3) works out to be a binary divider for a divide by 6 (2 + 4) using an AND gate. This drives U4, the decade counter, to deliver a 10-Hz or 1-Hz output range. U5 is a dual one-shot and generates reference and reset signals. Those who are familiar with computer I/O circuitry and RS-232-C will recognize the input driver.

J2, an extra phono jack on the input, allows for a measurement of ac line frequencies. R2 limits the input signal. U7 starts to respond at about 3-V peak and burns out at 36-V peak. With the proper voltage divider, signals up to about 600 V can be measured.

The power supply uses standard voltage regulation as recommended by manufacturer data books. The charger is a modified current source. The value of the current regulator is determined by R3; R3 should be chosen so as to supply proper current. D1 is picked to handle 5-8% over the battery voltage. The input accepts voltage up to U9's maximum rating (about 36 V). The minimum voltage must be at least 2 V higher than the battery to allow for component voltage drop.

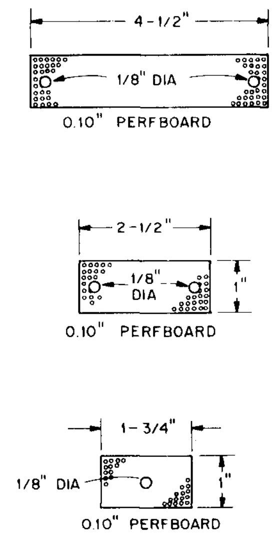


Fig 2—Instructions for preparing component boards 1, 2 and 3.

Construction

Wire-wrap pins and sockets are used throughout the project. Components can be directly soldered to the PC board, but the use of IC sockets is recommended. Directly soldering an IC to the PC board may destroy sensitive chips and makes removing a bad one difficult. I mounted my display and drivers, counter section and charger/supply on separate boards.

Cut three pieces of 0.10-inch perfboard as shown in Fig 2. One piece is cut 1 inch × 4 1/2 inches. Label this board no. 1. A second piece is cut 1 1/2 inches × 2 1/2 inches; this is board no. 2. Board no. 3 is cut 1¼ inches × 1 3/4 inches. Drill two centered holes 1/8-inch diameter on each narrow end of board no. 1 and 2. Drill one 1/8-inch diameter hole in the center of board no. 3.

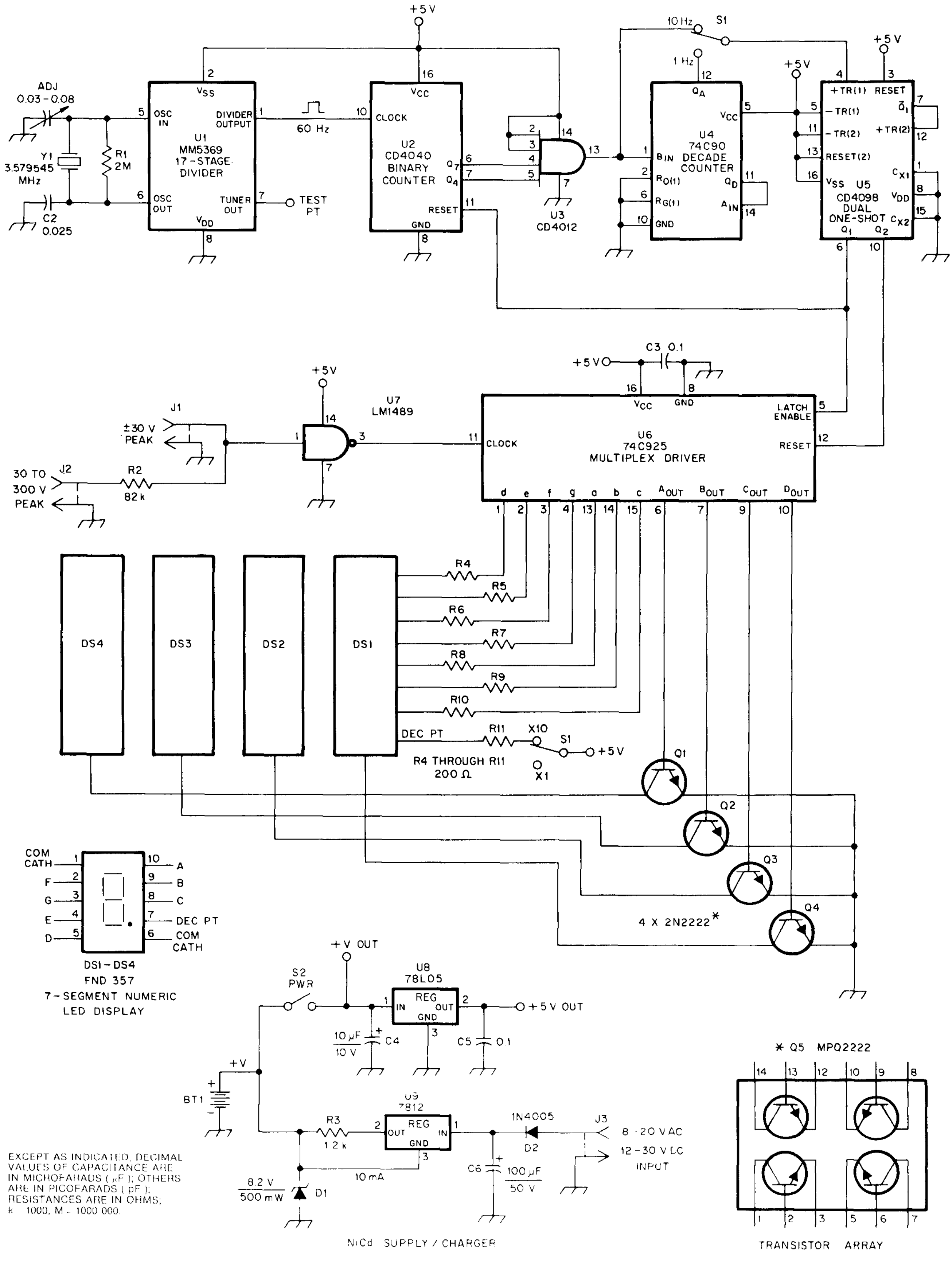
Next, acquire an enclosure measuring 2 inches × 4 inches × 5 inches. Using the perfboard pieces as templates, drill holes in the box that will hold your PC boards as follows (allow room for the cover): Center board 1 on the bottom edge of the box in a lengthwise position as shown in Fig 3. Center board 2 near the other edge of the same panel. Mark the holes. Center board 3 on another panel end and mark the holes. Drill each hole carefully. On the same panel where board 3 was placed, drill two holes in which to place the BNC connectors. The holes should be placed so that they lie outside the edges of where board 3 will be mounted, but are no less than 1 inch from the box top. Two switches and a phono jack for the charger are centered in the same fashion on the opposite end (a second switch may be added for future expansion of the counter).

Punch out, or nibble, a hole centered under board 1 for the LED display. If FND 357s are used, each LED display measures 3/8 inch × 9/16 inch. Allow enough room to view the whole display. (If a different display is used, board 1 may have to be cut somewhat larger.) Glue a small piece of red filter over the cut area. Small screws and nuts can be used to secure the filter, if desired.

To secure the sockets firmly to the PC board, use a small amount of cement. Check to see that the adhesive does not come in contact with the socket pins. U6, U7, Q1 through Q4, R4 through R11 and the display should fit on board 1. The remaining components, except for the charger/supply, are placed on board 2. Single wire-wrap pins can be inserted as needed to mount other components. The wire runs should be as short as feasible. Use care when installing board-to-board wiring. Allow enough wire to reach all components without pinching.

Mount the phono jacks and switches in

[1] National Semiconductor, *1984 Linear IC Databook*.
[2] T. Dorbuck, ed, *The 1978 ARRL Radio Amateur's Handbook*, (Newington: ARRL, 1977), p 134.
[3] M. Wilson, ed, *The 1987 ARRL Handbook*, (Newington: ARRL, 1986), pp 27-29 to 27-32.



EXCEPT AS INDICATED, DECIMAL VALUES OF CAPACITANCE ARE IN MICROFARADS (µF); OTHERS ARE IN PICOFARADS (pF); RESISTANCES ARE IN OHMS; k = 1000, M = 1000 000.

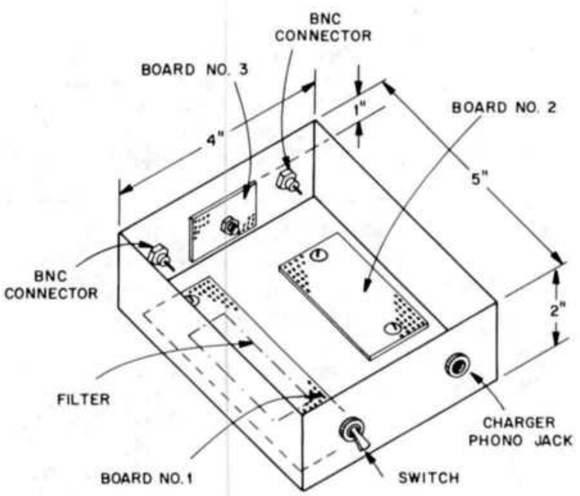


Fig 3—A pictorial of the counter's internal parts.

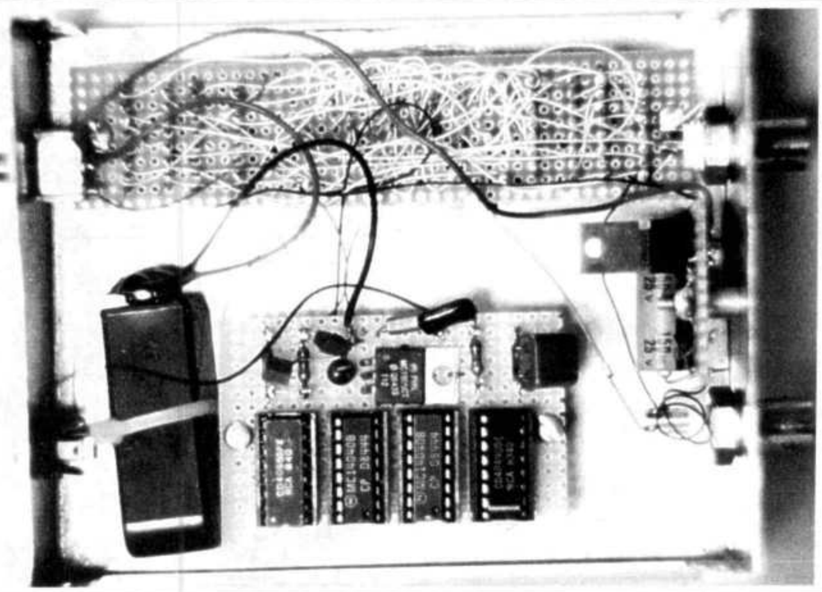


Fig 4—An inside view of the frequency counter. The charger board is mounted between the two BNC connectors to the right. The battery is tied to the standoff. The display driver is mounted at the bottom center. Hidden from view is the display; it is mounted underneath the wire-wrap board.

the box as shown in Fig 4. Battery-clip wiring may come directly from the back of the power switch and to the chassis-ground lug on the BNC connector.

The finished boards are mounted to the box using 3/4-inch standoffs, or screws and nuts, set to hold the pins and connections away from the chassis. The display components should be no closer than 1/8 inch from the box. Mount the charger away from connections.

Wire the boards to each BNC connector. Use 26-gauge wire-wrap wire; this is the minimum recommendation for power wiring.

Initial Powerup

Check the power supply with the battery disconnected. Place an ammeter between the battery clips and attach appropriate charger values to the input. (Charger values were discussed in an earlier section. Be sure the plug used matches J3. Calculator-type chargers of at least 8-V ac are sufficient.) The meter should read approximately 10 mA. Measure the voltage across the battery clips; 8-8.5 V dc should be present. Attach a battery and turn on S2. Measure the voltage at U8, pin 3. It should be about 5-V dc.

Now apply a signal of at least 3 V P-P at J1. A signal should appear on the display. If your results are not as expected, go back and check wiring connections. If wire-wrap construction techniques were used, be sure the wires are not touching each other.

Adjustment and Testing

Making the initial adjustment of the frequency counter requires several pieces of test equipment and two steps. An accurate 60-Hz reference (or an ac line) and oscilloscope can be used, or, for better accuracy, employ an RF frequency counter and scope.

Test 1 uses a frequency counter and a scope. Attach the frequency counter to

Fig 1—Schematic diagram of the frequency counter and charger.

BT1—9-V NiCd battery.
C1—3-8-pF trimmer.
C2—25-pF disc ceramic.
C3, C5—0.1-μF disc ceramic.
C4—10-μF, 10-V electrolytic.
C6—100-μF, 50-V electrolytic.
D1—8.2-V, 500-mW Zener.
D2—1N4005 or equiv.
DS1 through DS4—FND 357, common cathode displays or equiv.
J1, J2—Chassis mount BNC phono jack.
J3— Surface mount mini-phone jack.
Q1 through Q4—NPN 2N2222.
Q5—MPQ2222 transistor array.
R1—2-MΩ, ¼-W resistor.
R2—82-kΩ, ¼-W resistor.
R3—1200-Ω, ¼-W resistor.
R4 through R11—220-Ω, ¼-W resistor.
S1—DPST toggle or slide switch.
S2—SPST switch.
U1—MM5369 timebase.
U2—CD4040 12-stage binary counter.
U3—CD4012 CMOS 4-in NAND gate.
U4—74C90 CMOS decade counter.
U5—CD4098 (4528) CMOS one shot.
U6—74C925 display mux-driver.
U7-LM1489 quad-line receiver.
U8—78L05, 5-V regulator.
U9—7812, 12-V regulator.
Y1—Color-burst crystal (3.579545 MHz).
Misc Parts
Battery clips.
Chassis box 2 inches × 4 inches × 5 inches.
Mounting hardware.
Perfboard (VECTOR P phenolic) 0.10-inch spacing.
Red filter plastic.
VECTOR T44 pins or equiv.
Wire-wrap wire.
10, 14 and 16-pin wire-wrap sockets

Most parts are available from Jameco Electronics, 1355 Shoreway Rd, Belmont, CA 94002, tel 415-592-8097. NiCd batteries and red filter plastic are available at Radio Shack. Four NPN transistors, 2N2222, may be substituted in place of Q5. R4 through R11 may be replaced using a 220-Ω, 8-DIP package. Both Q5 and the resistor package are sold by Allied, 401 E 8th St, Fort Worth, TX 76102.

Low-Noise Audio Preamplifier

A low-noise audio preamplifier is useful in many audio frequency applications and is a handy add-on accessory for the pocket-sized audio frequency counter. This unit works equally well with a stereo or desk microphone.

Fig 1A is the schematic of the preamp, which is ac coupled at the input to minimize noise pickup. The RC network leading to U1 presents a high-impedance load (greater than 1 MΩ) to the input device. C1 is used for proper noise immunity, but it may be eliminated if no RF/noise problems are present with the preamp.

U1 is a low-power and extremely low-noise op amp (the LM358 is equivalent to half of an LM324). It can run on any single-voltage supply from 4 to 30 V and is ideal for mobile and amateur applications. The op amp's sensitivity changes little over the entire supply voltage range.

Construction Practices

Use proper grounding techniques when employing the preamp. One of the preamp's characteristics is low internal noise; be careful not to generate noise at the inputs. Keep all leads as short as possible. A potentiometer used to control gain in audio circuits may be substituted for R7. Preamps may be cascaded for higher circuit sensitivity, but the sectional gain should be decreased before other circuits are added.

If cascading is done, capacitors should be eliminated from all but the first circuit. Other single-voltage op amps also work in this design. If the preamp is used in a low-input sensitivity circuit, check the noise ratings.

Circuit Operation

The preamp's input sensitivity is flat at 5-mV P-P from 50 Hz to 15 kHz. This input level is at 5 mV, the noise threshold, and it produces a clean output of 0.2 V P-P; the output is more than enough to drive most amplifier sections. With a slight increase in input (to about 20 mV across the same range), the output reaches 1 V. This is certainly enough to drive a transistor. Most low-impedance microphones easily drive the input to this level. With a buffer on the output, this preamp can even drive a small speaker directly.

The input can be increased to a maximum of about 0.2 V. At this voltage level, the output is greatly distorted above 30 kHz and disappears at 60 kHz. The distortion is in the form of a sawtooth and a square wave, and it is still ideal for driving counters. Also, the signal is clean up to 30 kHz and the output is about 3 V P-P. See Table 1's test results for input signal versus frequency.

Table 1 was compiled using a 6-V supply to allow for worst-case conditions when running the preamp on a 9-V battery. If the voltage is increased to 12 V or more, the output response remains stable up to the limits of the audio spectrum because of the circuit gain. With input limited to 0.2 V and a gain of 50, a minimum of 10 V swing is required just to reach maximum output without clipping. At TTL and similar levels, saturation is reached long before 10 V and the unit barely puts out enough voltage to reach levels indicated in the test. In the intermediate input ranges, the usable frequencies are dc to 100 kHz, with 20-mV RMS worst case for 1-V output.

Table 1

Signal Versus Frequency Test

+V = 6 V dc; input = sine wave; all signals levels P-P

TTL Out		
2.5 Peak	5 Hz	20 mV
dc + signal	50 Hz	25 mV
	500 Hz	25 mV
	5 kHz	25 mV
	10 kHz	30 mV
	50 kHz	30 mV
	100 kHz	Unstable
1-V P-P		
Clean waveform	5 Hz	10 mV
	50 Hz	18 mV
	500 Hz	18 mV
	5 kHz	18 mV
	10 kHz	18 mV
	50 kHz	22 mV
	100 kHz	60 mV

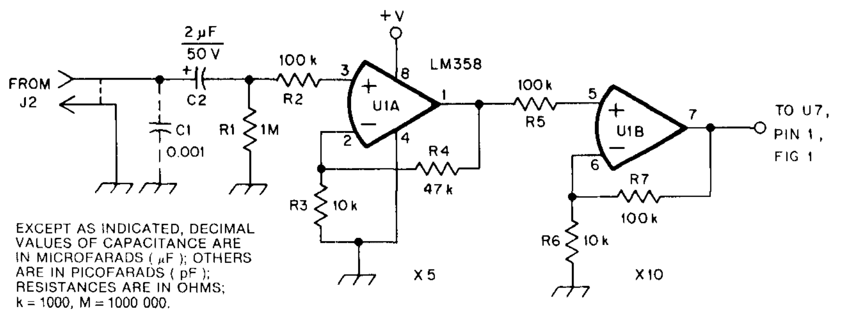


Fig 1A—A preamplifier can be used to improve the sensitivity of the pocket-sized audio frequency counter. The circuit is comprised of a low-noise op amp (LM358), that runs off a single 4- to 30-V supply. Input sensitivity is 35-mV RMS at 50 kHz (worst-case frequency); sensitivity improves below that (see Table 1). These specs are necessary for an output that drives U1. J2 is used for a high-sensitivity input. With a potentiometer inserted in place of R7, as much as 0.5 V can be applied to the input. No damage occurs from overdriving this circuit up to about 30 V; the frequency counter will blank out as the circuit starts to overdrive. If this should happen, vary the component values and supply voltage.

the test point on U1 for a reading of 3.579545 MHz, the crystal frequency. If you don't get this frequency, make adjustments to C1 as needed. Set the scope for 0.2 ms/div, 2 cm/div, and ground lead to the negative battery side. Monitor U5, pin 6, for a narrow pulse every second or 1/10 second, depending on S1's position.

Test 2 uses a dual-trace scope with a 60-Hz reference on channel A. Set the oscilloscope for 1-Hz full scale and attach probe B to U1, pin 1. Set the scope for 2 V/div, chop, and while laying A over B, adjust C1 until both traces match. Accuracy depends on how well the signals line up.

Conclusion

Whether you wire wrap or directly solder the components onto the PC board, you may wish to use a different circuit-board layout. The layout is not critical. My board was configured to save space.

The range of this frequency counter can be extended. Accuracy decreases by a factor of 10 each time a range is added because the display has only four digits. Cascading 7490s and changing the pin wiring on U2 and U3 may be considered. When adding components to this design, you will have to compensate the change by supplying more battery power to the counter.

This useful instrument is handy for doing basic audio work. Any signal shape from a 0.2-ms pulse to a 1-Hz sine wave can be measured. Any oscilloscope probe or clip lead arrangement will work on the inputs. This circuit will stretch the limits of your imagination!

By Bill Olson, W3HQT
Box 1655A, RFD 1
Burnham, ME 04922

Solid-State Construction Practices, Part 4

In the past three columns I have covered components, circuit layout, enclosures, connectors, thermal considerations and transistor handling for use in construction projects at VHF and above. This month I will concentrate on microstripline construction techniques.

Microstrip Notes

A microstrip transmission line, or microstripline, consists of a conductor above a ground plane. For VHF and UHF work, a microstripline usually takes the form of a copper strip etched on one side of a piece of double-sided PC board material. The back side remains unetched to act as a ground plane. Microstrip circuitry is especially useful at VHF and above where transmission lines can be combined with etched capacitances and inductances—etched pads take the place of discrete capacitors and inductors. Having most of the components for a circuit etched as circuit-board traces makes for simplified construction and ease of duplication.

As with any transmission line, two important microstripline parameters you must know are the characteristic impedance (Z_0) and the electrical length (λ_m). These numbers must be known to design a microstripline to do a specific job—such as to act as a 1/4-wavelength 50-ohm line.

The characteristic impedance of a microstripline depends on the ratio of the line width (w) to the height of the line above the ground plane (h), as well as the dielectric constant (E_r) of the material separating the two conductors. See Fig 1. Table 1 shows Z_0 values for various w/h ratios for two common dielectric materials: Teflon® -fiberglass or Duroid® , E_r = 2.4; and G-10 fiberglass-epoxy, E_r = 4.9. You can use Table 1 to find the impedance of a microstripline if you know the line width and circuit board thickness.

Because of fringing effects, all of the RF field between the conductor and ground plane is not concentrated in the dielectric; some is in the air above the dielectric. To find the electrical length of a microstripline, we first must know the effective dielectric constant (K_{eff}), which takes into account fringing effects in a particular line. The value of K_{eff} is always less than the value of E_r and is always somewhere between E_r and 1 (the E_r of air is 1). As the w/h ratio of a given line increases, there is less of a fringing effect and K_{eff} moves closer to E_r. See Table 1.

You can use the following equation to find the physical length of a wavelength in microstrip. Units can be anything convenient, as long as they are the same for λ_m and λ_0.

$$\lambda_m = \frac{\lambda_0}{\sqrt{K_{eff}}} \qquad \text{(Eq 1)}$$

where
λ_m = the wavelength in microstripline
λ_0 = the free-space wavelength
K_{eff} = the effective dielectric constant see Table 1)

Dielectric Properties

While G-10 fiberglass-epoxy PC board material, or its fire retardant equivalent (FR-4), is the most common dielectric

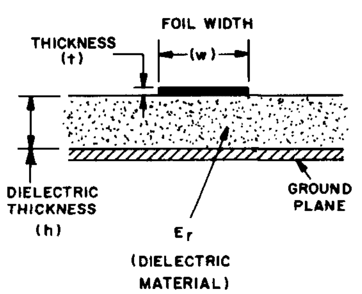


Fig 1—Cross-sectional view of typical microstripline construction.

Table 1
Microstripline Impedances

E_r = 2.4			E_r = 4.9		
w/h	Z_0	K_{eff}	w/h	Z_0	K_{eff}
0.2	165.1	1.80	0.2	123.2	3.22
0.4	132.8	1.84	0.4	98.60	3.33
0.6	114.2	1.87	0.6	84.45	3.41
0.8	101.3	1.89	0.8	74.67	3.48
1.0	91.42	1.91	1.0	67.19	3.54
1.2	83.34	1.93	1.2	61.11	3.59
1.4	77.01	1.95	1.4	56.35	3.63
1.6	71.78	1.96	1.6	52.42	3.67
1.8	67.30	1.97	1.8	49.08	3.71
2.0	63.39	1.99	2.0	46.16	3.75
2.2	59.93	2.00	2.2	43.58	3.78
2.4	56.84	2.01	2.4	41.27	3.81
2.6	54.05	2.02	2.6	39.20	3.84
2.8	51.52	2.03	2.8	37.33	3.86
3.0	49.23	2.04	3.0	35.63	3.89
3.2	47.13	2.04	3.2	34.08	3.91
3.4	45.21	2.05	3.4	32.66	3.93
3.6	43.44	2.06	3.6	31.36	3.95
3.8	41.81	2.07	3.8	30.16	3.97
4.0	40.30	2.07	4.0	29.05	3.99
4.5	36.98	2.09	4.5	26.61	4.04
5.0	34.19	2.10	5.0	24.56	4.08
5.5	31.80	2.12	5.5	22.82	4.11
6.0	29.73	2.13	6.0	21.31	4.14
6.5	27.93	2.14	6.5	19.99	4.17
7.0	26.34	2.15	7.0	18.84	4.20
7.5	24.92	2.16	7.5	17.81	4.23
8.0	23.66	2.17	8.0	16.89	4.25
8.5	22.52	2.17	8.5	16.07	4.27
9.0	21.49	2.18	9.0	15.32	4.29
10.0	19.69	2.19	10.0	14.02	4.33

material used in amateur microstrip construction, there are other, more exotic, materials. Used regularly in military and commercial equipment, such materials are beginning to show up in amateur construction, especially at microwave frequencies. These dielectrics, such as Rogers Duroid and 3M Teflon-fiberglass, are basically a Teflon board bound together with fiberglass or a fiberglass-type material. The 3M material uses a woven fiberglass cloth to hold everything together, much like G-10 board, while Duroid uses a powdered binder. Both have similar dielectric constants: Duroid, with an E_r around 2.2 to 2.3, and 3M glass-Teflon, with an E_r around 2.5 to 2.6. They can be treated as equivalent for most amateur work.

There are also a number of ceramic-based dielectric materials. Ceramic-filled board material, such as 3M Epsilam 10®, consists of Teflon mixed with powdered ceramic (alumina in this case) to produce flexible dielectric sheets. The relative dielectric constant of such material is between 5 and 10, depending on the mix. Hard ceramic (alumina) is commonly used in commercial and military microwave equipment. It has relatively low loss, and because of its high E_r, produces very small circuits. Alumina, however, requires special techniques in manufacturing and installation and is used rarely in amateur construction.

Many factors must be taken into account when selecting a dielectric material. Basically it's the old game of trading off cost and ease of use versus performance and, in some cases, physical size. The higher the E_r, the smaller the circuit will be. But, the smaller the circuit gets, the more difficult it will be to define accurately. The thicker the board, the bigger the circuit; the thinner the board, the smaller the circuit—same trade offs as above.

Loss is a big factor in selecting a dielectric material. G-10 is very lossy and rarely used above 1.3 GHz, but it is readily available and cheap (often free!). Teflon-based boards have various loss factors (much better than G-10). They are usually harder to scrounge and very expensive when purchased new. Generally, the thinner the board and the higher the E_r, the higher the loss—but all are suitable for use to well over 24 GHz.

The final factor in the trade off game is ease of use. The thicker board materials (1/32, 1/16 and sometimes 1/8 inch) are easiest to use because they stay relatively stiff while they are being handled. Thin 0.010-inch Teflon board feels pretty much like copper foil, which is largely what it is! Teflon and G-10 (FR-4) boards are used most often in amateur applications and can be etched using common home workshop methods. Hard alumina circuits are most often manufactured using photo lithography techniques more akin to those used in semiconductor processing than PC board manufacturing. Note that a 50-ohm line on 0.025-inch-thick alumina is 0.025-inch wide—not easy to cut to size with an X-acto® blade.

Scaling Microstrip Circuits

So, now you know what dielectric materials you *don't* want to use, and you know which ones you have on hand. The next obvious question is "How do I convert a circuit from one dielectric material to another?" For example, say you want to take a circuit designed for 1/32-inch Teflon-glass board and build it on 1/16-inch G-10, or you have a circuit for 1/32-inch Teflon-glass, but only have 1/16-inch Teflon-glass board on hand. Obviously the final circuit will be a different size, but where are the changes to be made?

Basically, the circuit should be divided into transmission lines and lumped capacitances. This can be difficult at times since a short, low-impedance line looks like a lumped capacitance. My experience has been to treat such a line as a capacitance, and not a transmission line. I do it this way because some of the microstrip transmission line approximations start to break down for very short or very wide lines because of fringing and radiation effects.

Anyway, the new board should have transmission lines of the same impedance, Z_0, and the same electrical length, λ_m, as the old board. If the new board material is the same as the old, the line widths will change, and that's it. The w/h ratio of line must be kept constant to preserve Z_0. For example, microstriplines of a given impedance on a 1/32-inch G-10 board would be half as wide as on 1/16-inch G-10. The line lengths will remain the same since λ_m for a given w/h ratio is constant as long as the dielectric material is the same (see Table 1).

When changing to a material with a different dielectric constant, not only do you have to be careful to preserve Z_0, but also to preserve the electrical length, λ_m, of the line. To keep Z_0 the same, w/h ratio will change. The physical length of the line will change as well (see Eq 1). For example, a transmission line of a given electrical length will be shorter on G-10 than on Teflon.

The lumped capacitance sections are not as straightforward to convert. For lumped capacitance sections that are roughly square, you can use the following equation to scale the approximate size to the new material.

$$C = \frac{K E_r A}{D} \quad \text{(Eq 2)}$$

where

C = capacitance
K = a constant
E_r = the relative dielectric constant of the board
A = the area of the capacitive plate
D = the thickness of the board.

I always try to keep the shape of the capacitive section approximately the same and adjust the overall size to maintain the proper C. Remember this scaling information only gets you into the ball park; there are many second order effects that will change things slightly, but you should be able to get to where the normal tuning range of the variable circuit elements can make the new circuit equal the old one.

Bending Microstrip Lines

Often we want to turn a corner with a microstrip line to get to a connector or to shorten the physical length of a circuit. If you just make a right angle turn (see Fig 2A), there is a discontinuity that represents an impedance bump in the line. To compensate, the corner is usually cut off at a 45-degree angle. The exact place to cut here depends on frequency, line impedance and dielectric constant, but good results can be obtained by cutting as shown in Fig 2B. This will give a good match to 20 GHz or so; that's probably good enough for our purposes!

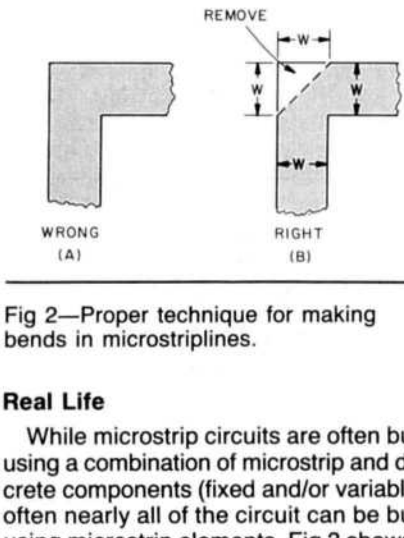


Fig 2—Proper technique for making bends in microstriplines.

Real Life

While microstrip circuits are often built using a combination of microstrip and discrete components (fixed and/or variable), often nearly all of the circuit can be built using microstrip elements. Fig 3 shows a typical amplifier layout with only a few discrete components. Bypass capacitors can be open-circuited, quarter-wavelength, low-impedance lines. RF chokes can be quarter-wavelength high-impedance lines. Tuning elements can be closely spaced sections of microstrip capacitance that can be soldered together or hacked back off to tune a circuit (sort of adds new meaning to the term "trimmer" cap!). The input and output blocking capacitors are more easily realized using discrete components (chip

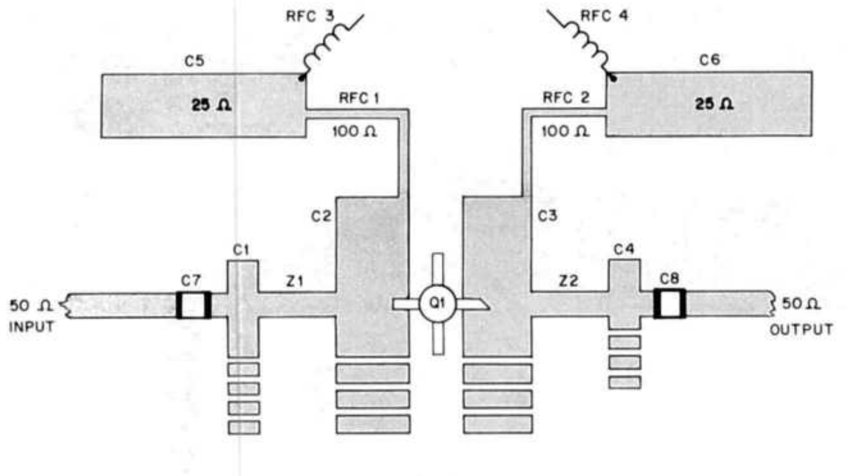


Fig 3—A typical microstripline amplifier board. C1-C4 are tunable microstrip capacitances. They are trimmed by soldering across additional pads or by cutting away some foil. C5 and C6 are bypass capacitors made from 25-ohm, ¼-wavelength lines. C7 and C8 are chip-type blocking capacitors. Z1 and Z2 are microstrip transmission lines. RFC1 and RFC2 are ¼-wavelength, 100-ohm lines. RFC3 and RFC4 are low-frequency chokes that lead to the collector and bias supplies.

caps), as are the low-frequency bypass capacitors and chokes.

Fabricating Microstrip

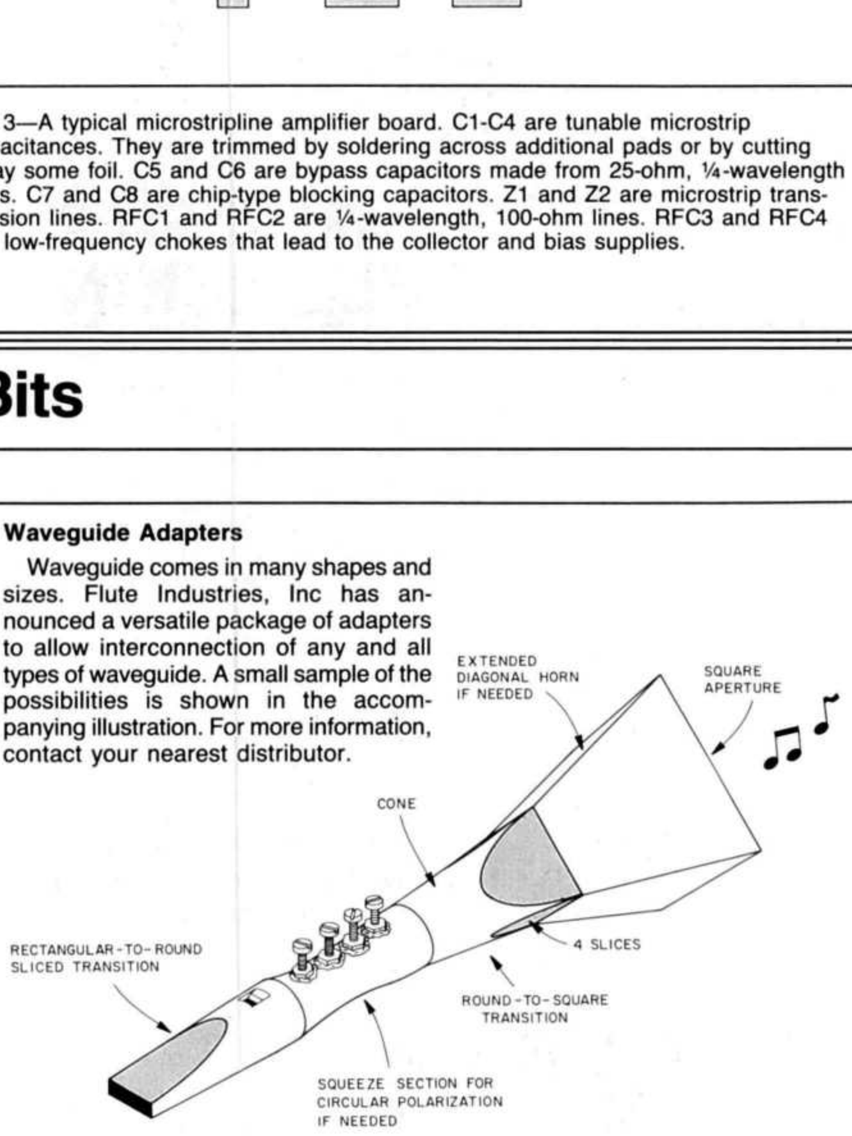
While photographic processes are often used to fabricate microstrip PC boards, one-of-a-kind boards can be produced reasonably by just cutting the copper with an X-acto knife and peeling away the unwanted foil. A better method (especially on Teflon boards where peeling is *not* easy) is the "X-acto etch" method advocated by Dave Mascaro, WA3JUF. First draw the circuit outline on the board. Then cover the whole board with clear Mylar packaging tape, making sure there are no bubbles. Use a sharp X-acto knife to remove the tape from the areas on the board where the copper is to be removed. You can then etch the board in a ferric chloride solution available from many electronics supply houses. See Chapter 24 of *The ARRL Handbook* for etching methods. When etching is complete, peel the tape off and voila!

That's it for this month. Hope everyone's ready for spring VHF and UHF conditions!

Bits

Waveguide Adapters

Waveguide comes in many shapes and sizes. Flute Industries, Inc has announced a versatile package of adapters to allow interconnection of any and all types of waveguide. A small sample of the possibilities is shown in the accompanying illustration. For more information, contact your nearest distributor.



Thirteenth Annual Eastern VHF/UHF/SHF Conference

The 13th Annual Eastern VHF/UHF Conference will be held May 15-17, 1987 at Rivier College, Nashua, NH. Rivier College is located near Rt 3, a short distance north of the MA state border.

A Friday night hospitality room is featured that includes a swapfest. Technical talks given by well-known VHFers round out Saturday's agenda, and Sunday's schedule includes noise figure and antenna gain measurements. These programs are part of a host of other activities of interest for the VHF/UHF experimenter and operator.

To preregister for the Conference, send $14 to David Knight, KA1DT, 15 Oakdale Ave, Nashua, NH 03062 before May 4. Registration at the door is $20. For additional information on other program features, reduced rates for Novices and overnight accommodations, contact Lewis D. Collins, W1GXT, Publicity Chairman, 10 Marshall Terrace, Wayland, MA 01778, tel 617-358-2854 (6-10 pm EST).

WØRPK-AMSAT BBS Changes

The WØRPK-AMSAT Bulletin Board System is now running on a dedicated personal computer and telephone line. The telephone number continues to be 515-961-3325. Preregistration is no longer required for access to AMSAT News Service bulletins, the latest orbital elements and UoSAT News. The system is continuously available for AMSAT-OSCAR users 24 hours per day, seven days per week. The system is now equipped with a 300-1200-2400 bps modem. System enhancements are planned.—Tnx Ralph Wallio, WØRPK