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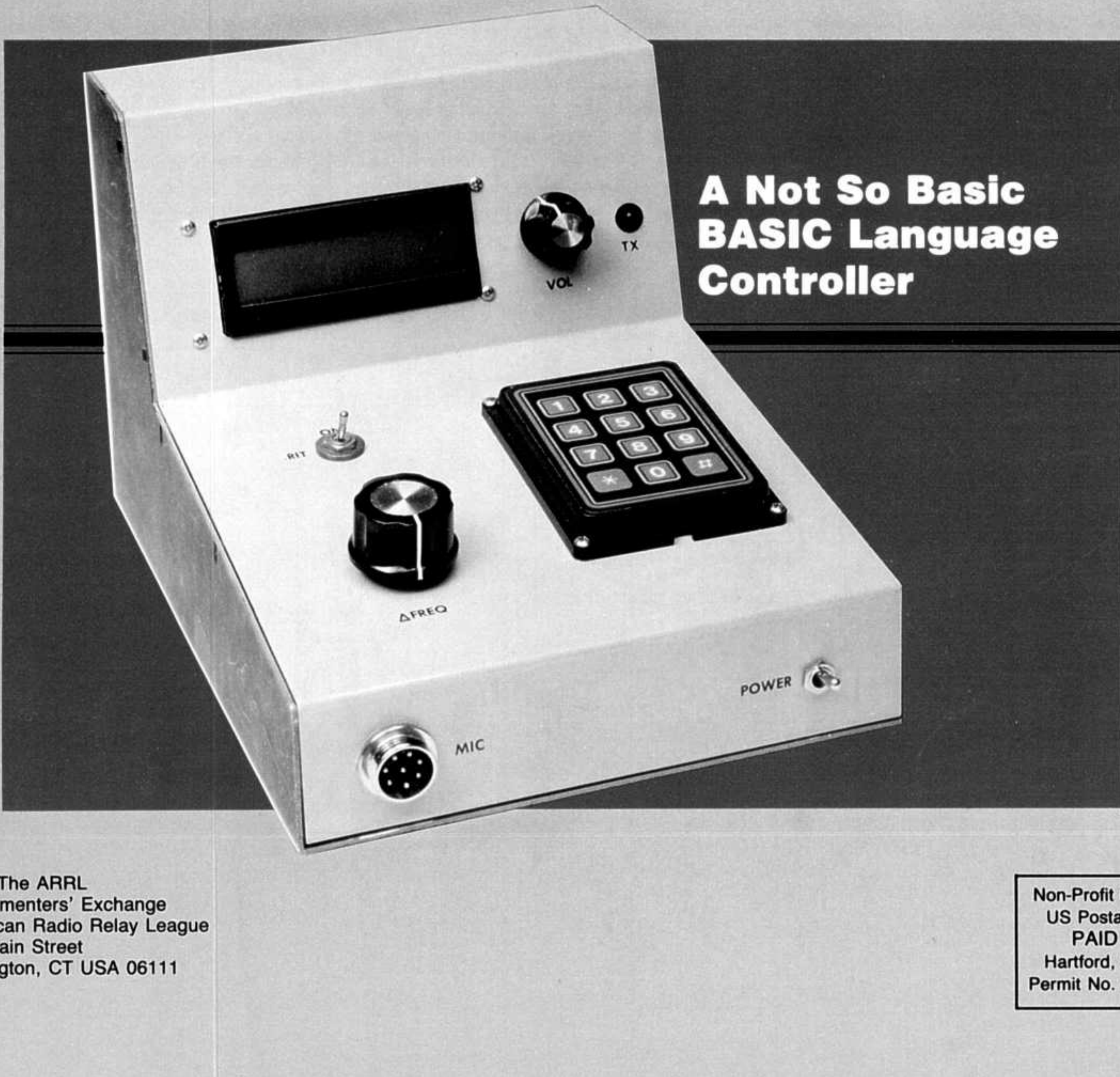
A Not So Basic BASIC Language Controller



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Robert Hinrich, WM6H, designed and built this 8052AH-BASIC based micro project controller.

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2) document advanced technical work in the Amateur Radio field
3) support efforts to advance the state of the Amateur Radio art.

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Both theoretical and practical technical articles are welcomed. Manuscripts should be typed and double spaced. Please use the standard ARRL abbreviations found in recent editions of *The ARRL Handbook*. 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*.

Empirically Speaking . . .

Strategic Planning

There's an important difference between *long-range planning* and *strategic planning*. Long-range planning can be simply an extension of present trends modified somewhat by foreseen events or influences. Strategic planning, however, is deciding *what* you want to do *when* but not *how* you're going to get there. For example, a strategic business decision might be to have a 40% market share by a certain date, which can then be given to an effective executive to make happen.

Amateur Radio faces a number of strategic issues, all of which have technical components of varying magnitudes. The subject of *frequency allocations* leaps to mind because of the FCC's recent decision to reallocate the 220-222 MHz band to land mobile use. While there is much to be said on this subject (and has been in the September and October issues of *QST*), we can profitably use this *QEX* space to identify some other major issues. Let's hope the Commission's action does not strangle the 56-kbit packet-radio baby in its crib. Suffice it to say that Amateur Radio experimenters need spectrum in which to develop new technology. The League's fight to retain access to the 220-222 MHz band continues on regulatory, legislative and judicial fronts. In 1993 or thereabouts, we probably will be facing another World Administrative Radio Conference with a goal of finding more HF broadcast spectrum below 9 MHz and possibly frequency space for other services in the microwave bands. Before then, we're likely to face domestic threats in some of the bands that are listed as shared in the international Table of Frequency Allocations.

The next strategic issue affecting most amateurs is *radio-frequency interference*. Practically every ham has encountered RFI complaints by neighbors because of poorly designed consumer electronic equipment. This is a good-news/bad-news story. The good news is that we have federal law PL 97-259 that empowers the FCC to regulate susceptible devices; the bad news is that they haven't done it (yet). The good news is that some progress has been made voluntarily by the ANSI C63 committee, some manufacturers of mature electronic devices and local interference committees; the bad news is that new devices are moving in from the front, flanks and rear in densely populated areas. There's a formidable technoeconomic problem here (how do we convince manufacturers and consumers to pay the price of limiting susceptibility?). There is an educational shortfall as well (how many neighbors blame RFI on hams who aren't on the air; how many hams don't operate for fear of RFI?). Of course, RFI is a two-way street. Hams are experiencing interference from low-power intentional radiators as well as unintentional radiators such as computers—even in one's own shack!

Then there's the matter of *antenna restrictions* that prevent amateurs from erecting antennas beyond certain heights or at any height in a growing number of neighborhoods. Technology says the antennas work better (for the longer distances) when at heights ranging from 75 to 120 feet—and on some bands, even higher. Yet, social pressures in the forms of zoning restrictions and convenants are trying to say that a good antenna is a low or no antenna. If you're house-hunting, consider it a bad sign if a drive through the neighborhood reveals no antennas. PRB-1 has helped. There's more work to do to fight antenna restrictions.

Biological effects of nonionizing radiation continues to hit the news periodically, and stimulates the flow of regulatory and legislative juices. Certainly hams want no part of "zap thy neighbor or thyself" with RF energy, but neither do we want to see needless restrictions on Amateur Radio operation based on hasty conclusions. The League's Bioeffects Committee is watching this one closely.

QEX would welcome correspondence on the above strategic issues. It appears that the *what* is known—we want to see progress on these issues or at least keep them from further restricting our freedoms. The *how* needs to be addressed—how can technology be brought to bear on these problems?—*W4RI*

8052AH-BASIC Micro Project Controller

By Robert Hinrichs, WM6H
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A few years ago, I read an article featuring the Intel™ 8052AH-BASIC micro controller chip.[1] I thought at the time that this device could be used as the central building block for a number of amateur projects I was planning. The 8052AH-BASIC has a complete, built-in BASIC language interpreter; add a handful of external components and a simple—yet complete—high-level-language, microprocessor-based controller could be built. This microprocessor would be perfect for self-contained microcomputer or embedded controller applications. Now that part suppliers are starting to offer the 8052AH-BASIC at reduced prices, I decided it was time to get busy.

The result of my effort was the micro project controller (MPC). The entire MPC project, along with program development and application tips for the 8052AH-BASIC IC, is presented here. The power of the 8052AH device, coupled with the simple MPC design, offers amateurs who lack hardware building experience or sophisticated software development tools (PROM programmer or ultraviolet erase lamps, for instance) the means to build their own microprojects.

MPC Design Goals

In order for the MPC to serve as the microcontroller for a number of different projects, the following design goals were established.

(1) A simple hardware design using a single 12 V dc power source. Additional power supplies should not be required for programming EEPROM, RS-232-C interfaces and so on. The design should also incorporate visual information display and keypad I/O.

(2) A complete BASIC implementation. This is a function of the ROM interpreter on board the 8052AH-BASIC chip. One of the primary uses for this design would be to perform simple dedicated tasks currently done by my station computer (HF MUF prediction, satellite tracking, beam heading-distance calculations and CW keying). A "tiny" or integer BASIC would not be adequate for this purpose. Off-loading simple applications to the MPC would free my station computer for complex applications requiring human interaction or more storage and computing power.

(3) The microcontroller should be easy to program from a computer keyboard, eliminating the need to open the enclosure to reconfigure the hardware. This same controller, with proper I/O interface, can also be used as a remote control unit (RCU) for a transceiver equipped with a computer interface. Only the application software would change. Because the 8052AH-BASIC chip is controlled via a serial link, it might be possible to interface this RCU with a TNC and use packet radio to upload program revisions to a remote installation (a repeater controller, for instance).

Before starting the MPC design, I considered purchasing commercially available kits or a complete single-board package using the 8052AH-BASIC device. These kits were either too complex for my purpose—a BASIC program several hundred lines long will fit into the 8-kbyte EEPROM used with the MPC—or didn't meet my design objectives. What I wanted to do with the MPC was create a complete package usable for development purposes and in stand-alone applications.

The final design, presented here, meets these goals. It includes an I/O keypad, information display and on-board, programmable, nonvolatile program/data memory and a single 12 V dc power source.

The 8052AH-BASIC Chip

The MPC is built around the INTEL 8052AH-BASIC micro controller chip. Most microprocessors run object code; the 8052AH-BASIC runs a form of BASIC. (This is an oversimplification, but to a programmer, the chip appears to be thinking in BASIC.) Assembly language routines, cross-assemblers or target compilers are not required: The 8052AH meets you halfway.

This remarkable device contains 256 bytes of RAM, three 16-bit timer-counters, a built in real-time clock, a full-duplex serial channel, serial printer port and 8 kbytes of internal ROM containing the 8052AH-BASIC language called BASIC-52. BASIC-52 is a fairly complete BASIC implementation, containing many statements found in most popular microcomputer BASICs. The BASIC-52 package includes structured loop control statements like DO-WHILE, DO-UNTIL, ON-GOSUB, in addition to the usual BASIC language FOR-NEXT, IF-THEN-ELSE and GOTO statements. Numbers in the range +1E-127 to +0.99999999E+127 can be expressed to eight digits of significance in four number bases; integer, decimal, hexadecimal and exponential. Logical operators and relationals, TRIG functions (SIN, COS, TAN, and ATN), and basic string operations are also included. BASIC programs written on other microcomputers can be used with BASIC-52 almost verbatim, usually requiring only minor modifications.

If time-critical routines must be coded in assembly language, BASIC-52 can access them with the CALL statement. An advanced feature of BASIC-52 is the ability to extend the language interpreter: This allows the programmer to create statements not included in BASIC-52. *The 8052AH User's Manual*[2] completely explains this feature and is a good place to start for anyone interested in applying this device to other microcontroller projects.

Using the MPC

The MPC consists of a microcontroller core built around the 8052AH-BASIC, 8 by 8 kbytes of RAM and EEPROM, plus some TTL "glue" logic. The nonvolatile EEPROM takes the place of program EPROM in the MPC allowing long-term program storage. Erasing and programming the EEPROM is accomplished with software; special EPROM programming hardware is not required. The MPC remains the same from project to project—only the I/O interfaces and programs will change to meet specific application requirements.

Your personal computer will serve as the host during the application development cycle. Linked to the 8052AH-BASIC via the MPC's serial port, your computer can be used to create BASIC programs for the MPC. Once downloaded, the program source code is debugged while resident in the MPC's RAM. Once the program is working properly, it is saved in EEPROM with the BASIC-52 PROG command.

Using one of the BASIC-52 reset options, (the PROG2 command), your program is prepared for execution after a reset or power-up. Disconnect the serial communications link, button up the MPC enclosure and your project is complete.

MPC Hardware

The MPC core schematic is shown in Fig 1. The MPC's memory map is shown in Table 1. An external interrupt is provided when the # key is pressed, but may be used as required by the application hardware.

As I specified in my design goals, the MPC operates from a single 12 V dc power source (negative to chassis). The negative voltages necessary for the MPC's RS-232-C serial interface are

[1]Notes appear on page 15.

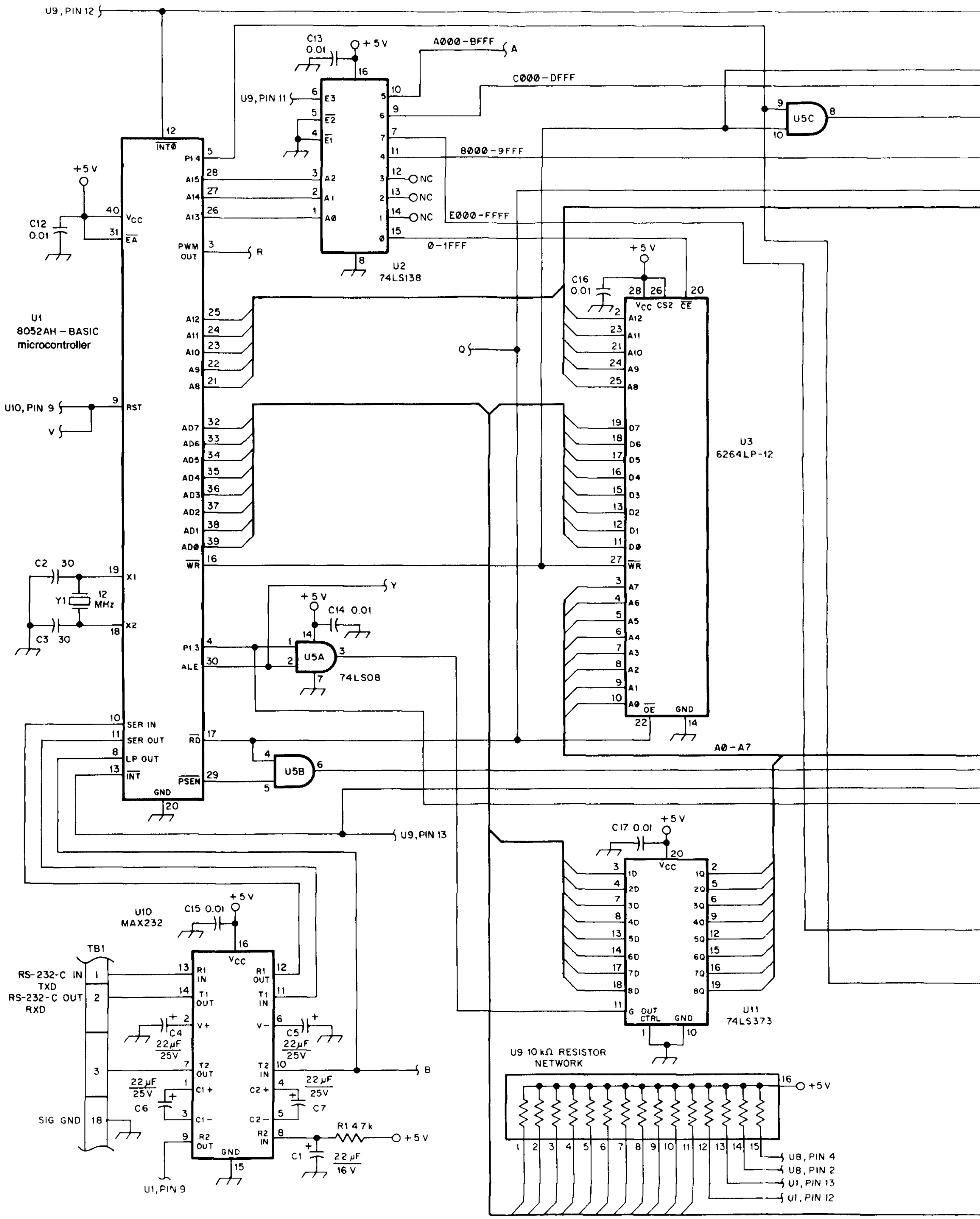
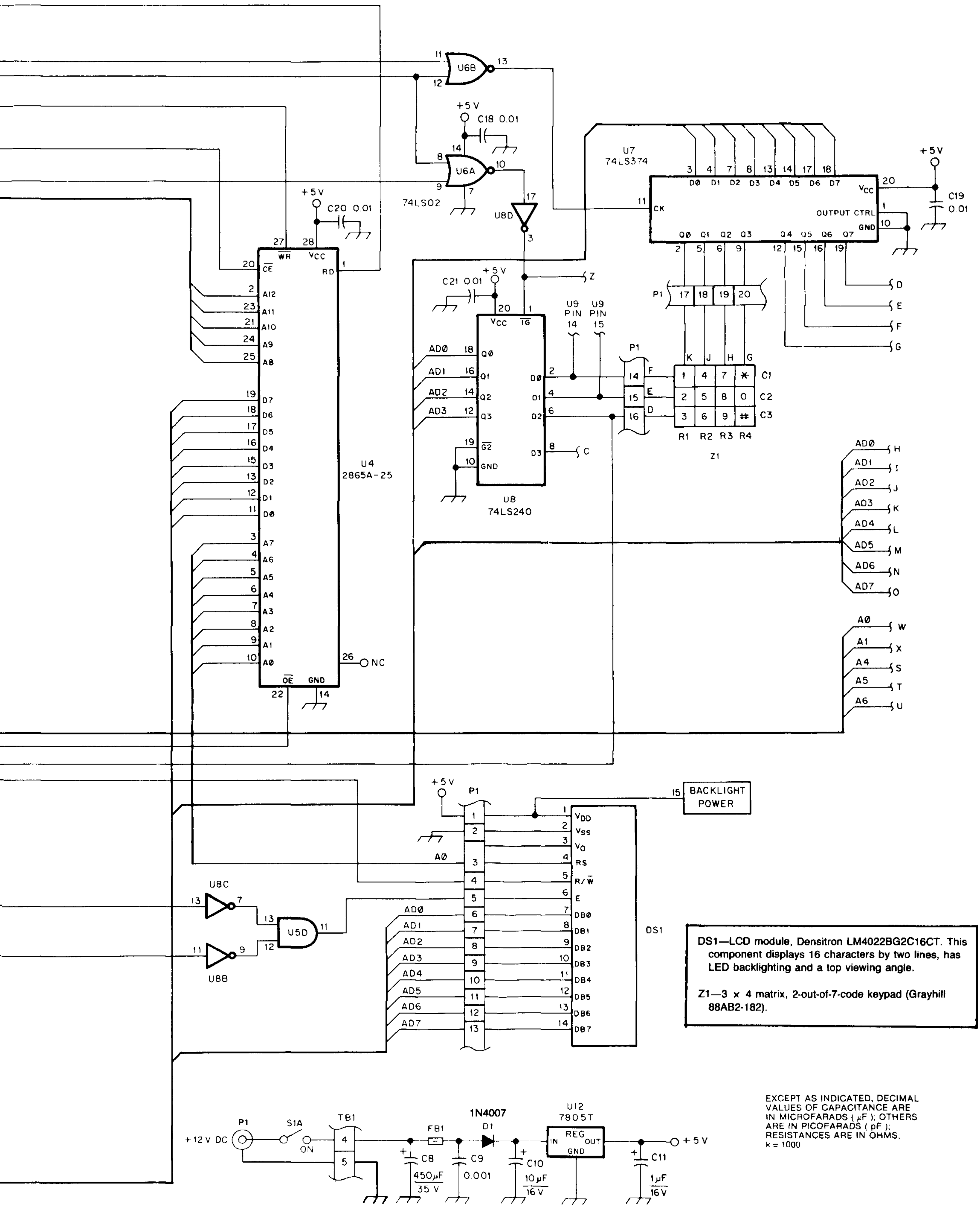


Fig 1—Schematic drawing of the WM6H micro project controller. The application interconnections are designated alphabetically



and correspond to points shown in Figs 2 and 3. See text.

Table 1—Listing of the MPC memory map.

$0000 – $1FFF	System RAM.
$2000 – $7FFF	Not used.
$8000 – $9FFF	Program and nonvolatile data storage RAM.
$A000 – $BFFF	Application specific.
$C000 – $DFFF	Keypad and application I/O.
$E000 – $FFFF	LCD display module.

The $ preceding the MPC memory map denotes hexadecimal notation.

developed separately by the Maxim MAX232 chip.

The 2865A EEPROM, U4, is very simple to use; think of it as RAM with a long write cycle (10 ms). EEPROM specifications include: 5 V dc write operations, 10 year data storage life (without batteries) and approximately 10,000 rewrites per byte.

Program transfer from your computer to the MPC EEPROM is accomplished by the BASIC-52 command PROG; the 8052AH-BASIC handles the control signals and maintains the proper delays. As a bonus, the 8052AH-BASIC allows the same EEPROM to be used for permanent storage of input variables under control of the applications program (that is, from the computer keyboard). This means that the EEPROM can program itself under control of the program running in it! When the EEPROM is written to, it goes into an internal write cycle during which it is "out to lunch" and can't be accessed for program fetches of the BASIC source code. If the EEPROM ready/busy pin is connected to the DMA (direct memory access) of the 8052AH-BASIC input, the 8052AH-BASIC will poll this pin and wait for the EEPROM to come back on line. A special DMA-like input—actually an interrupt—makes this possible. This DMA input function is enabled by including the following statements in your program:

```
DBY(38) = DBY(38) .OR. $02
     IE = IE .OR. $81
```

Programming the EEPROM is then simple a matter of writing to it, as in:

```
XBY(09F00H) = NV_DATA
```

(The DBY/XBY statements are detailed in the *8052AH-BASIC User's Manual.*)

Using EEPROM in place of EPROM can be very different. The 8052AH-BASIC will allow multiple programs, or "ROM files," to reside in a single device. When the PROG command is issued, the program stored in RAM is placed at the end of the previous program and issued a sequential reference or ROM file number. This requires the programmer to be aware of how much EPROM memory is left and when to perform EPROM erasing procedures when using the 8052AH-BASIC. With EEPROM, we can write over old program versions without that hassle.

Only the first program in the sequence can be run on power-up, so we must trick the 8052AH-BASIC into thinking it is always programming a device for the first time. The procedure is as follows: After debugging your program in RAM, write a value of $0FF into location $8010 of the EEPROM while in the COMMAND mode:

XBY(8010H) =0FFH <CR>

(<CR> equals the pressing CARRIAGE RETURN, ENTER or NEW LINE key). Then issue the PROG command. The 8052AH-BASIC will always think it is programming a fresh device and store it in the "ROM 1" file.

MPC Display

The LCD module's interface is a little unusual. I wanted a display with backlighting for use in the mobile application (RCU). Densitron Corp's LCD module fit the bill, but the 8052AH-BASIC doesn't interface cleanly with the display module's timing requirements. The solution was to make the 8052AH-BASIC think it was programming an EPROM when writing to the display. I have found this technique to be fast enough for most applications, and it's a reasonable trade-off given the simplicity of the hardware interface. The sample program in Table 2 includes a display driver subroutine (lines 320 to 355) that demonstrates this technique.

Be sure to specify top or down viewing when ordering the LCD module. The best viewing angle for maximum clarity is about 25° above or below the centerline of the display's viewing plane. With this in mind, give some thought to where you will mount the display with respect to where you will mount the MPC. This concern can be eliminated with a "super twist" LCD module, but a negative voltage would be required.

MPC

Testing the MPC is straightforward and easy to do. First, turn the power supply on and check for correct V_{CC} at all IC sockets before you install any ICs. Once all voltages have been verified as correct, turn off the power and install the ICs. Connect your computer to the serial interface (TB1, 2 and 18) and run a terminal program. Turn the MPC on and press the space bar on your computer keyboard. (The 8052AH-BASIC powers up using an AUTOBAUD routine and expects a space to the first character it sees. This routine matches the MPC's serial data rates with your computer—assuming that it doesn't find an application program in memory.) Once the AUTOBAUD routine is, successful, the MPC sign-on message will be displayed on your terminal and you're in business.

BASIC-52 operates in either the COMMAND (immediate) mode or RUN (interpret) mode. After the sign-on message is displayed,

Table 2—The WM6H MPC wake up message program.

```
1     REM TEST PROGRAM TO DEMO DISPLAY DRIVERS
4     STRING 400,11
6     W=.0001
8     R=65536-W*XTAL/12
10    DBY(40H)=R/256:DBY(41H)=R.AND.0FFH
12    XBY(0C000H)=87H
14    $(1)="hello world"
16    $(2)="de WM6H"
55    REM INITIALIZE THE LCD MODULE
60    PUSH 38H:GOSUB 320:PUSH 38H:GOSUB 320
65    PUSH 0CH:GOSUB 320:PUSH 2:GOSUB 320
70    PUSH 1:GOSUB 320:PUSH 80H:GOSUB 320
80    REM DISPLAY MESSAGE
85    GOSUB 500
90    REM DISPLAY MYCALL
95    GOSUB 600
100   REM LOOP FOREVER
101   GOTO 100
105   REM
106   REM
320   REM LCD MODULE CONTROL ROUTINE
325   POP CNTRL_VAL
330   XBY(1F00H)=CNTRL_VAL
335   DBY(31)=0:DBY(30)=1
340   DBY(26)=0DFH:DBY(24)=0FFH
345   DBY(27)=1FH:DBY(25)=0
350   PGM
355   RETURN
360   REM DISPLAY ASCII VALUE
365   POP DSPL_VAL:POP DSPL_LOC
370   XBY(1F00H)=80H.OR.DSPL_LOC
375   DBY(31)=0:DBY(30)=1:DBY(26)=0DFH:DBY(24)=0FFH
385   DBY(27)=1FH:DBY(25)=0:PGM
395   XBY(1F00H)=DSPL_VAL
400   DBY(30)=1:DBY(26)=0E0H:DBY(24)=0
410   DBY(25)=0:PGM
420   RETURN
500   REM DISPLAY MESSAGE ROUTINE
505   FOR I=0 TO 10:PUSH I:PUSH ASC($(1),I+1):GOSUB 360
510   NEXT I
515   RETURN
600   REM DISPLAY MYCALL ROUTINE
605   FOR I=0 TO 6
610   PUSH I+0C0H:PUSH ASC($(2),I+1):GOSUB 360
615   NEXT I
620   RETURN
```

the COMMAND mode is accessed, and you can enter and run your program. If an application program is found in memory by the 8052AH on power-up or after a reset, the RUN mode is entered immediately, and you can only get to the COMMAND mode by sending a Control C (CTRL C <CR>) or when the program executes an END statement.

Programming on the MPC

To demonstrate how simple the MPC is to use, I'll take you through a complete software development cycle—from program entry to stand-alone application.

You may want to use a PC and a text editor to create a file with the sample program. Be sure that your editor doesn't insert any special control characters that the 8052AH-BASIC won't understand (some popular word-processing programs do this). When you are finished entering the program text, upload the file to the MPC.

Our example application program is shown in Table 2.[3] All this particular program does is clear the display and then print a "wake-up" message. Place your PC in terminal mode and type the following:

RAM <CR>
NEW <CR>

Once these two commands have been issued to the MPC, enter the program in as shown in Table 1. After a few lines have been entered, type:

LIST <CR>

Any statements entered to this point should be listed. If you find a mistake, correct it now.

The 8052AH-BASIC does not accommodate standard flow control for batch input or download functions: It expects every line to be typed in one at a time, which is not practical for very long programs. There are ways to get around this problem, however. One successful solution is to place five spaces between each end-of-line and the line number of the next line of source code. At 4800 bit/s, the 8052AH-BASIC has time to scan the line, write it into RAM (along with a little overhead) and prepare for the next line number. This method isn't bulletproof; in fact, it didn't work with my PC compatible. Fortunately, the terminal program I run on this machine can insert a delay after each line during ASCII transfers: A delay of 0.2 seconds does the trick. If your communications/terminal program doesn't have this feature, you may have to enter the program by hand or write your own program to read a file and send it to the MPC over your PC's communications port using a delay after each carriage return.

Debugging the program

After you've entered the source code, issue the following command:

RUN <CR>

The "hello world" greeting should be displayed on the LCD module. If not, stop the program execution with Control C and LIST the program to check it for accuracy. Break points can be entered where necessary by inserting a line number and "END" statement. Some statements, like PRINT, can be executed in COMMAND mode. For instance, variable values can be displayed with the PRINT statement (PRINT X) after the program has halted at a break point. If you suspect a problem with the LCD module, redirect the display data to your terminal. Once this program has been completely debugged and is working correctly, change the program to display your call and RUN it.

Storing the Program in EEPROM

After your program is working the way you want it to, the next step is to prepare it to run when the MPC powers up with a dedicated application. Make sure that this program is stored in the ROM 1 file. Halt your program with Control C and enter the following statement:

XBY(8Ø1ØH) = ØFFH <CR>

Because this is the first program stored in the MPC EEPROM, you can omit this step, but it *will* be required the next time you enter the program. The actual programming takes place after you enter

PROG <CR>

A *1* should be displayed. After a short wait, READY should be displayed, indicating that programming is complete. To let the 8052AH-BASIC know you want your program to be run, and not to enter the command mode after the next reset on power-up condition, type

PROG2 <CR>

The MPC stand-alone test is next. Turn the MPC off and disconnect the serial link. Reapply power and your program should run, displaying the "hello world" greeting and your call on the LCD module.

Case Study—MiniMUF 3.5

I decided to use MiniMUF 3.5 as a test case to gauge the degree of difficulty in transferring a typical application program from a personal computer to the MPC. Only the basic MPC circuit, Fig 1, was required to perform this study.

The first part of the process was very simple and took only a few minutes. I downloaded MiniMUF 3.5 from the AMRAD BBS and verified its operation on my computer. Next, I loaded the program into my word processor to do a global search and replace for all the BASIC statements that I knew would not work in BASIC-52 (these statements include CLS, COLOR, BEEP, LOCATE and PRINT A:B [which becomes PRINT A,B]). The next step was to run the program and see what happened. The first program crash was at the DEFFCN (DEFine FunCtioN) statement. I found all occurrences of the function statement—there were three—and substituted the complete formula. After two more hiccups—/\ became ** and = > became > =—the program ran.

The MiniMUF program on the MPC will prompt you for longitude, latitude, time, date and sunspot number, crunch the numbers and display an updated hourly MUF projection to a requested DX location. I had some surplus MPC memory, so I also included the great circle distance and bearing program from *The ARRL Operating Manual*.[4] Either of these programs can be selected when the MPC is powered up or after the # key is pressed.

The first step is to get the program running on the MPC using your terminal for I/O with BASIC-52's INPUT and PRINT statements. After this is accomplished, your own I/O drivers can be written to accept and display MPC keypad input for stand-alone operation.

Applications

In Figs 2 and 3, you'll find two application projects using the MPC. There is one important consideration when adding your application circuitry to the multiplexed data bus AD0-7. The 8052AH-BASIC data sheet mentions that noise pulses—due to capacitive loading—may cause the ALE line to glitch, and suggests that the total line load be kept under 100 pF. You can estimate about 10 pF per device added, but the stray capacitance produced by wiring, connectors and cables is hard to get a handle on. If you suspect that the total capacitance is close or equal to the 100 pF value, install an address latch with a Schmitt trigger strobe input in place of U11.[5] (A data bus transceiver can be added, but if you don't go overboard hanging devices on the bus you should have no problem.)

Application No. 1—the CW Keyer

Add the circuit illustrated in Fig 2, modify Table 1 with the lines from Table 2, delete line 101 (type 101 <CR> if you are directly programming the MPC), and the MPC can be used as a CW keyer.

The element speed, in microseconds, is "hard wired" in line

110, but the program could be modified to accept a value for keyer speed from the keypad and store it in nonvolatile memory. For faster speeds, it may be necessary to add an RC network for control of character element weighting. The output keying line shown is for positive keying (at current levels appropriate for a 2N2222A), but it can be modified to handle the voltage and current requirements of your transmitter.

The keyer described here is very basic. You can probably think of several enhancements to improve its performance, but once the transmitter interface has been worked out, any changes you wish to make will be to the software only. This points out one of the advantages of using the MPC: the keyer can take on a completely different character without your having to pick up a soldering iron.

One potential enhancement would be canned messages for contest work. These can be entered as ASCII strings in the keyer source program and down-loaded into nonvolatile memory along with the program. An ASCII-to-CW conversion subroutine would send these messages by interrupting the keyer program when the numbers 3, 6, 9 or # keys are pressed (the hardware shown in Fig 1 connects this column to the interrupt line). The number of messages could be expanded by coding other keypad combinations. With a little more complexity, messages from the keyer paddles, via a CW reader routine, would accept dot and dash information connecting the characters into an ASCII message string. A CW reader routine should contain a special learning cycle divided into one second slots. In each slot, (the start of which is signaled by the TX LED), a character would be started. If no

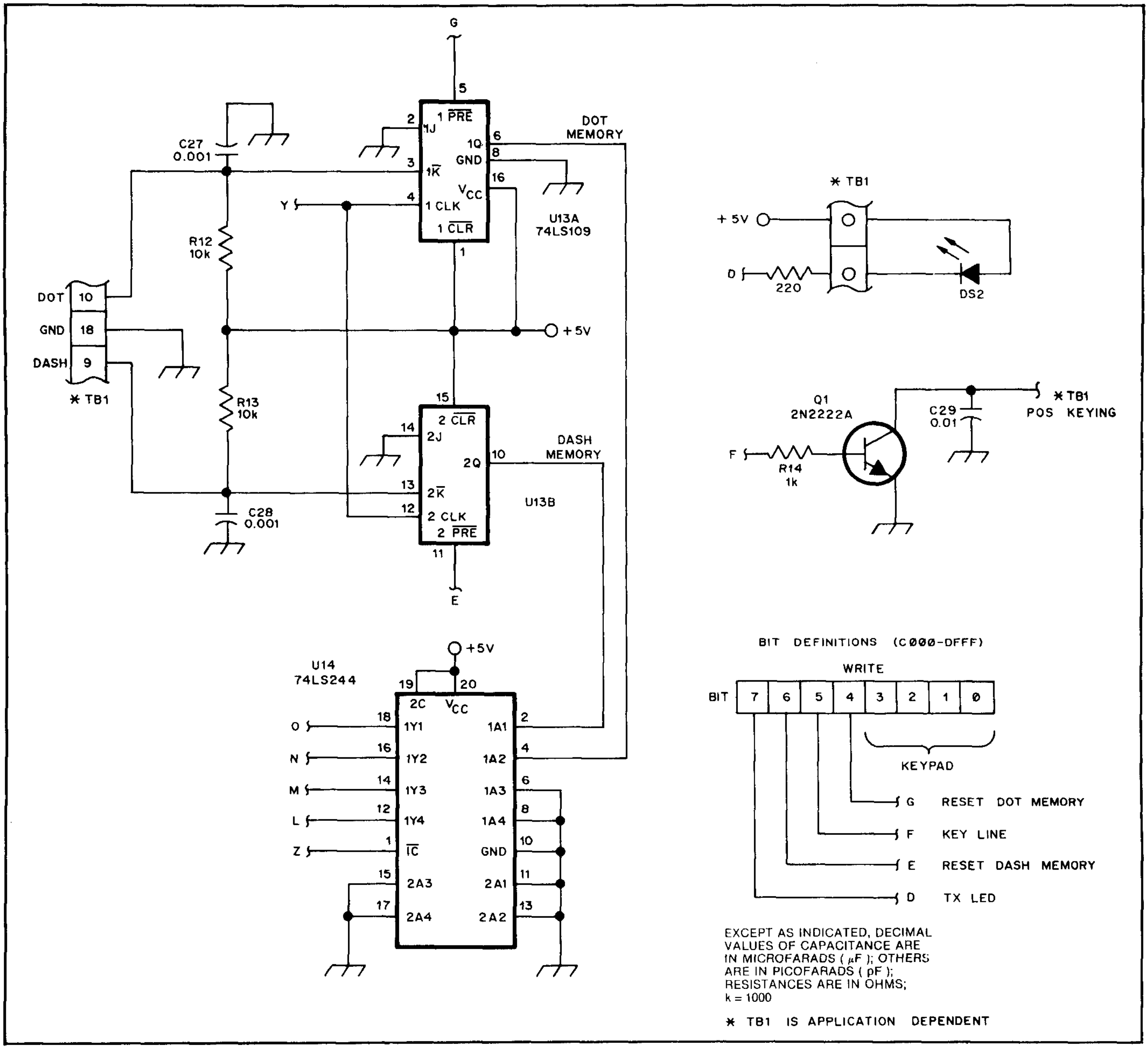


Fig 2—Schematic for the MPC CW keyer application. MPC application interconnections are listed alphabetically. See text.

C27, C28—0.001-μF disc ceramic.
C29—0.01-μF disc ceramic.
Q1—2N2222A.
R12, R13, R15—10 kΩ, ¼ W.
R14—1 kΩ, ¼ W.
U13—74LS109 dual J-K flip-flop.
U14—74LS244 3-state, octal buffer/line driver.

character was input during the slot, a space would be entered into the ASCII string. A specific keystroke on the keypad signals the end of the message.

Application No. 2—the MPC-RCU

With the addition of the circuitry in Fig 3, the MPC can be used as a remote control unit (RCU) for a Kenwood TS-440S MF/HF transceiver (equipped with Kenwood's IC-10 option) for mobile operations. Borrowing an idea from a commercial VHF/UHF system, the transceiver is locked in the car trunk with the MPC/RCU installed under the dash. Frequency and mode are entered via the keypad, as are frequency storage and recall operations involving the MPC/RCU EEPROM. Transceiver frequency changes can be performed in two ways: (1) The UP/DN switch on the rig's standard mobile mic and (2) with an A/D converter (ADC0809) reading the position of a potentiometer (R3, FREQ). In the A/D method, the MPC converts the position of the potentiometer into serial frequency commands and sends them to the TS-440S at 4800 bit/s. I find that the A/D method allows a faster tuning rate than the rate used with the microphone UP/DN switch. It closely emulates the speed of the TS-440's tuning dial. The A/D method is also a less expensive alternative to using a rotary position encoder.

Also shown in Fig 3 is a method of expanding the I/O of the MPC by using spare ADC0809 inputs. Switch position (S2—RIT/ON) is determined by doing an A/D conversion. The printer output pin of the 8052AH-BASIC is used to drive the optoisolator interface to the radio. Commands are output with the BASIC-52 PRINT# statement. The PWM pulse sequence output of the 8052AH provides the correct number of clock pulses to the A/D converter to eliminate polling for end-of-conversion.

The RCU made mobile operation possible for me. All TS-440S functions cannot be remotely controlled, however. The rig is broadband enough not to require remote control of its antenna tuner, but the lack of ALC and S-meter information in the TS-440S serial data stream, along with the inability to use some of the TS-440S operating features like notch, IF shift and speech processing, are drawbacks that should be considered before building the RCU.

In order to get a reasonable radio tuning range from the 8-bit A/D converter, the program I use gives a tuning resolution of 100 Hz when tuning with the potentiometer. Fine tuning with 10-Hz resolution is still available when using the UP/DN switches on the TS-440S microphone. Whatever the solution, it should not involve a rotary switch with discrete mechanical "clicks" or detents.

(continued on page 15)

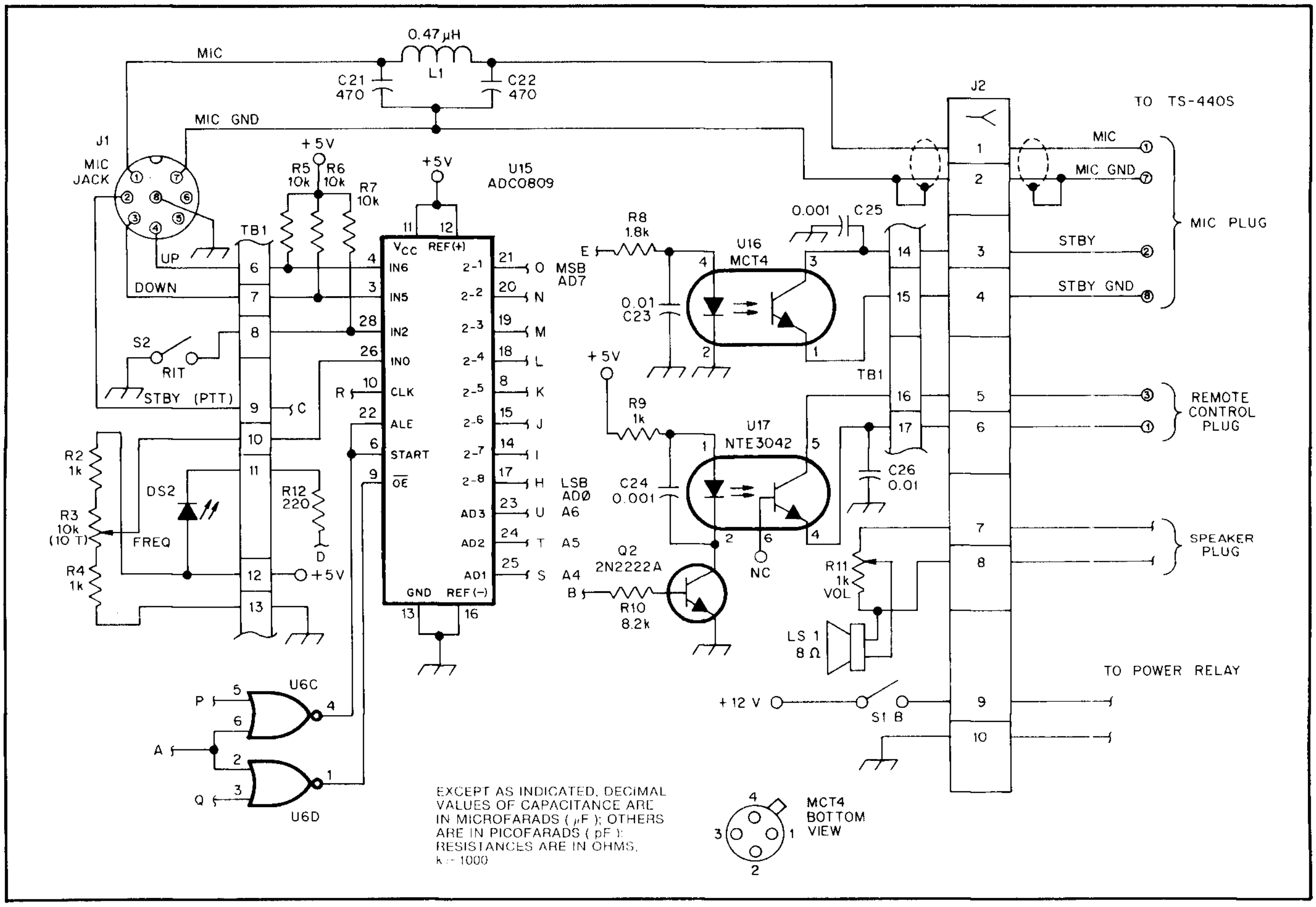


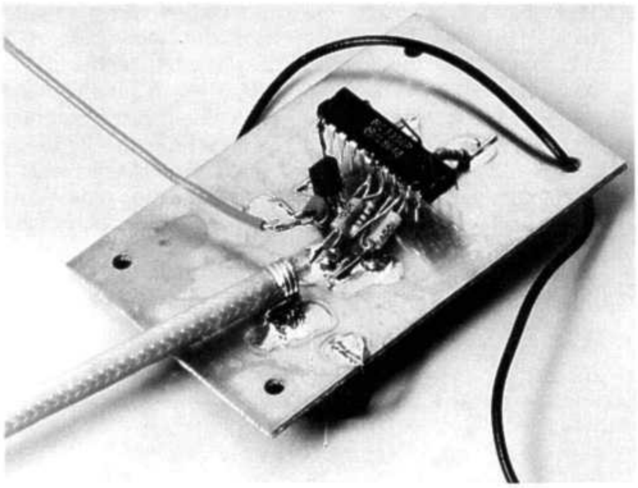
Fig 3—Schematic for the TS-440S RCU (remote control unit). MPC application interconnections are listed alphabetically. See text.

C21, C22—470-pF disc ceramic.
C23, C26—0.01-μF disc ceramic.
C24, C25—0.001-μF disc ceramic.
DS2—red LED.
LS1—8-Ω speaker.
Q2—2N2222A.
R2, R4 to R7, R9—1 kΩ, ¼ W.
R3—10-kΩ 10-turn potentiometer (Precision Bourns 3540S-1-103).
R8—1.8 kΩ, ¼ W.
R10—8.2 kΩ, ¼ W.
R11—1-kΩ potentiometer, audio taper.
R12—200 Ω, ¼ W.
S2—SPST miniature toggle switch.
U15—ADC0809 8-bit A/D converter with 8-channel multiplexer.
U16—MCT4 General Instruments optoisolator.
U17—NTE3042 Sylvania optoisolator.

A Logarithmic RF Detector for Filter Tuning

By Zack Lau, KH6CP
ARRL Lab Engineer

Did you ever shy away from building bandpass filters because you don't have a spectrum analyzer and tracking generator to tune up the filters? The advantage of being able to use a spectrum analyzer for filter tuning is the terrific dynamic range it offers: 60 dB or more. With that sort of dynamic range, you can usually tell whether a resonator is too high or low in frequency, even if the resonance is far from the design frequency. Commercially available spectrum analyzers are expensive, and building even a cheap spectrum analyzer involves a lot of time and effort.



Another Way

For those of you who don't have access to a spectrum analyzer and don't want to build one, here's an inexpensive alternative that I've devised and use for filter tuning. The logarithmic detector circuit shown in Fig 1 provides over 60 dB of dynamic range. (The MC3356 and similar ICs have been used as part of inexpensive spectrum analyzers.) Fortunately, this IC has enough frequency response to work well even at 10 meters.

Ideally, you'd use a sweep generator and oscilloscope in conjunction with a log detector, but that approach may be too expensive for the casual homebrewer. As an inexpensive substitute, I recommend using a QRP rig such as the Heathkit® HW-8 or HW-9 as a signal source, in conjunction with an RF attenuator. (I wouldn't mind if you were to join with me in a QRP QSO during a break from home-brewing!) The attenuator is needed to protect the rig from filter impedances other than 50Ω. Forty decibels of attenuation is needed between a 1-W transmitter and the RF detector. By placing the filter between a 30-dB attenuator and a 10-dB attenuator as shown in Fig 2, you can ensure that the filter sees the proper terminations. With this setup, you may have all that is needed to tune up any HF bandpass filter.

Remember that most QRP rigs aren't designed for continuous service—don't burn up the finals while endlessly tweaking. Also, inexpensive trimmer capacitors do wear out. Although some rigs have less than rock-solid stability, you would have to be building some extremely narrow filters to require great stability.

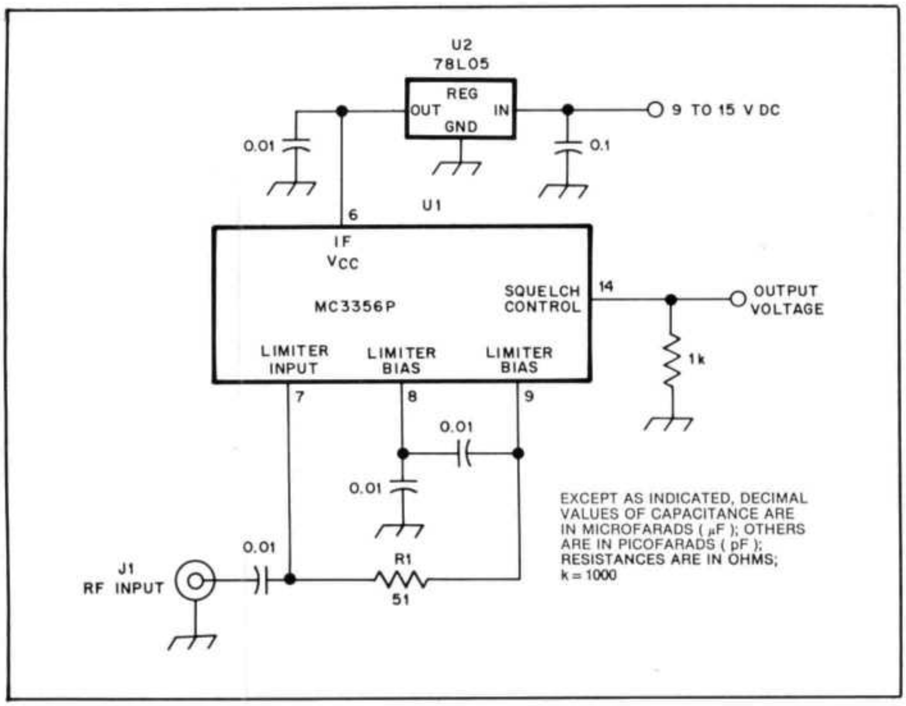


Fig 1—Schematic diagram of a simple log RF detector for filter tuning. R1 is a ¼-W, metal-film or carbon-composition resistor; a BNC connector is used at J1. Pins not shown on U1 are unused.

Construction

The log-detector circuit is too simple to bother making a PC board for it. Build the circuit on an unetched circuit board as shown in the title photo. This construction method allows for excellent grounding. Besides, you may find a use for the other circuits in the chip and building "dead-bug" fashion gives you easy access to the other pins. And, what if the chip you use is defective or *you* let all the smoke out? (Even professionals make mistakes . . .) The wise or experienced experimenter uses enough attenuation to assure that the maximum possible output power of the signal source can be accommodated, even if the power level oscillates wildly. Because you can probably build two or three of these dead-bug versions in the time it takes to etch the circuit board alone, why not build another as a spare?

Caveats

Unfortunately, the MC3356 IC isn't perfect: The output voltage is affected by

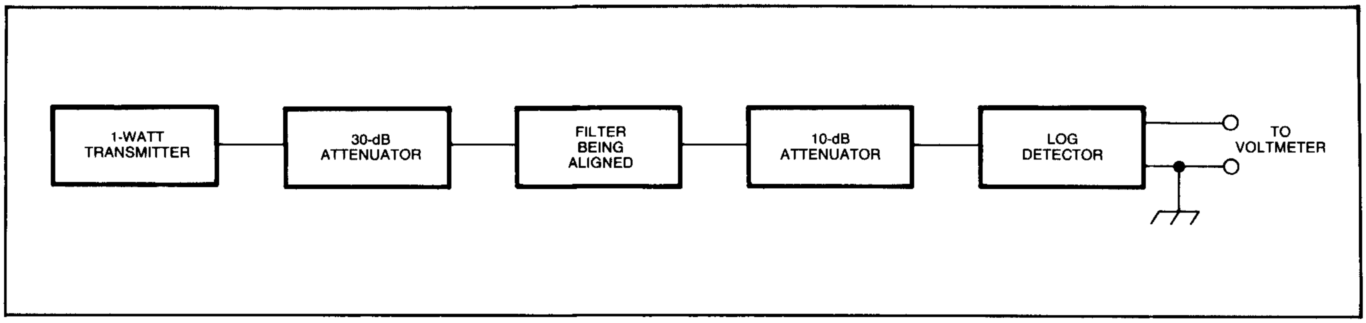


Fig 2—Placing the filter between 30- and 10-dB attenuators ensures that the filter will see proper termination impedances.

frequency, temperature and supply voltage. Of the three, supply-voltage variations are the easiest to solve: Use a 78L05 regulator.

The sensitivity of the IC v frequency is shown in Table 1. This sensitivity shouldn't be a problem when tuning typical narrowband filters. The frequency sensitivity is great enough, however, so that you can't use the IC as a broadband power meter, for instance, without compensation.

Using a 14.2 MHz, −20 dBm signal as reference, a 7.8-dB decrease in "calibrated" output reading was noted when the chip was sprayed with an aerosol coolant. Frost formed on the chip, so this could be regarded as a worst-case situation. Still, the IC's temperature sensitivity should be kept in mind if you intend to use it in a more sophisticated circuit. Below 7 MHz, you may want to put an attenuator in front of the detector, as the return loss drops to 10 dB at 2 MHz. Between 7 and 50 MHz, the return loss is at least 20 dB.

To those of you looking for suitable bandpass filter designs, I recommend you read Appendix 2 of *Solid State Design for the Radio Amateur.*[1] A table of filter designs covering the non-WARC, 160 through 6 meter bands is included, along with design and tuning procedures. Keep in mind that these designs assume the use of high-Q capacitors. Some cheap ceramic trimmers have a Q of only a few hundred. Unless the trimmer capacitor is only a small part of the total resonating capacitance, filter losses will be higher than calculated. I suggest you use silver-mica capacitors in parallel with air-variable trimmer capacitors.

[1]D. DeMaw and W. Hayward, *Solid State Design for the Radio Amateur*, 2nd ed, (Newington: ARRL), 1986.

Table 1

Frequency Sensitivity of the MC3356

Input Level (dBm)	3.56	10.7	14.2	28.5
	Frequency (MHz) / *Output Level (V)*			
0	0.594	0.560	0.542	0.469
−10	0.564	0.532	0.516	0.447
−20	0.499	0.468	0.453	0.388
−30	0.439	0.409	0.393	0.322
−40	0.371	0.343	0.328	0.258
−50	0.304	0.273	0.245	0.190
−60	0.240	0.211	0.193	0.119
−70	0.171	0.141	0.125	0.067
−80	0.119	0.085	0.072	0.060
−90	0.073	0.063	0.061	0.060

Notes: HP 8640B signal generator used as the RF source. Dc voltages measured with Fluke 77 DMM.

Bits

JARL Plans Second Amateur Radio Satellites

The long hiatus following the launch of JAS-1 (FO-12) is about to end. The JARL will soon begin work on another model of FO-12 with an eye toward launching their second OSCAR, JAS-1b. The JAS-1b design effort will focus on improving the tight power budget for smoother operations and antenna directivity in order to obtain a flatter radiation pattern. —*The JARL News*

AO-13 Telemetry Decoding Software

P3C.COM, used to decode AO-13's 400 bits/s PSK telemetry, is being offered by AMSAT-Australia for use on IBM® PC, or compatible, computers. P3C.COM captures telemetry, writes the data to disk and displays the following information: telemetry capture status, all available message blocks and Q block logical data groups. P3C.COM requires the use of an RS-232-C serial port, DOS 2.0 or higher, and the J. Miller (G3RUH) PSK demodulator. P3C.COM is available for a donation of $20, check or money order, to Project OSCAR, PO Box 1136, Los Altos, CA 94023-1136. All donations will be allocated to the development of future Amateur Radio satellites. —*Tom Francis, NM1Q*

DARC Verlag UHF Compendium

A recently translated version of the *DARC Verlag UHF-Compendium, Parts III and IV,* is now available in the US. This compendium covers many diverse UHF topics: power splitters and couplers, tunable notch filters, UHF transmit and receive converters and power amplifiers. Also contained in the compendium are articles of general interest to hams involved in UHF/SHF operations: ERP graphs, band plans and a complete European amateur UHF/SHF beacon list.

The price of the *UHF Compendium* is $36 airmail, $29 surface mail. Airmail delivery takes about one week, surface mail delivery requires approximately five to six weeks. For more information, contact Gerd Schrick, WB8IFM, 4741 Harlou Drive, Dayton, OH 45432 —*Tom Francis, NM1Q*

Nevada in the United Kingdom

Telecomme, a British company, has released a broadband Transmatch that is capable of handling up to 1 kW of RF power. Called the Nevada TM1000, the unit is able to match a wide range of antenna impedances with good efficiency on any frequency between 1.8 and 30 MHz. The capacitors and roller inductor are constructed to ensure negligible stray reactance at high frequencies. Each TM1000 is hand built and tested by the designer, Ernie Quinnel, G4JEV. Cost of the Nevada TM1000 is 120 pounds sterling. For more information, contact Telecomme, 189 London Rd, North End, Portsmouth, Hants, England PO2 9AE United Kingdom.

Components

By Mark Forbes, KC9C
5240 Whitney Blvd
Rocklin, CA 95677

Since the August column appeared, additional components and data concerning switched capacitor filters have come to my attention.

EG&G Reticon RF6609

EG&G Reticon, 345 Potrero Avenue, Sunnyvale, CA 94086, has introduced the RF6609, an elliptic 7-pole filter constructed from low-power CMOS. The filter is contained in an 8-pin DIP, so it takes up very little space. This is a good filter for applications requiring elliptical response. For more information about the RF6609, write to EG&G Reticon for a product data sheet.

Switched Capacitor Handbook

Maxim Integrated Products, whose switched capacitor filters were discussed in the August column, has published a handbook for switched capacitor filter applications. I haven't seen the book and do not know what it contains, but Maxim's recent product advertisements have provided a great deal of technical information, so I expect the handbook to follow suit.

Maxim also has an analog switch book available that should be a good source if you have applications requiring analog switches. To obtain copies of these books, contact Maxim Integrated Products, 120 San Gabriel Drive, Sunnyvale, CA 94086.

Analog Devices Programmable Delay Generator

A programmable delay generator, the AD9500, is being produced by Analog Devices. The AD9500 is programmable with a 8-bit word and can select up to 256 discrete delays. The lower resolution limit is *10 ps!* The upper limit is 100 μs. The 256 steps can be programmed with an upper limit between 2.5 ns and 100 μs. In other words, the resolution of the steps is determined by the upper limit as programmed by the 8-bit data word.

The part sells for $16 each in lots of 100. If you'd like more information on the AD9500, contact Analog Devices, One Technology Wy, PO Box 9106, Norwood, MA 02062-9106.

TDK EMI/RFI Components

TDK, makers of audio and video tape, also apply their ferrite and magnetics knowledge to EMI/RFI problem solving. They have an extensive line of products that includes ferrites of various types for EMI/RFI filtering on power-lines and power-transformers; ZISC series through-hole EMI/RFI filters; ferrite beads and chips; common mode choke coils; varistors and radio-energy absorbers.

TDK has a broad range of components for solving just about any type of interference problem. If you'd like a copy of their catalog, write to: TDK Component Engineering Laboratory, 1600 Feehanville Dr, Mt Prospect, IL 60056.

Five-Year Lead-Acid Battery

A 12-V sealed lead-acid battery, model no. PS-1242, is now available from Power-Sonic Corp. The battery is maintenance free, rechargeable, and best of all—from an amateur's point of view—it can be used for standby *and* deep-cycle applications.

Each cell measures roughly 3.5 × 2.75 × 4 inches, and has a capacity of 4 Ah. The battery is capable of up to 40 A of output. The price, in quantities of 500, is $16 each. Single unit quantities are no doubt more expensive, but this looks like a good battery at a decent price for ham applications. Other 12-V lead-acid batteries from Power-Sonic range from 700 mAh all the way up to 80 Ah (4.0 A—continuous—for 20 hours). The 80 Ah battery weighs approximately 50 pounds. Power-Sonic also produces 4- and 6-V lead-acid batteries. For further information, contact Power-Sonic Corporation at Box 5242, Redwood City, CA 94063.

Silicon Systems 2400 bit/s Modem Chip

A single-chip, 2400 bit/s modem is available from Silicon Systems. The K224 modem emulates V.22 *bis*, V.22, V.21 and Bell 212A/103 standards. Encoding schemes are FSK at 300 bit/s, DPSK at 600 and 1200 bit/s and QAM at 2400 bit/s. The K224 modem is designed to easily interface with most microprocessors.

This CMOS modem chip can operate at 12 V dc or 5 V dc (at 5 V, it dissipates only 120 mW) and is also pin and software compatible with Silicon Systems' older products, (K212, K221 and K222). For more information on the K224 modem, write: Silicon Systems, 14351 Myford Rd, Tustin, CA 92680.

Caddock Compact Power Resistor

Twenty-watt power resistors in TO-220 packages are available from Caddock Electronics. Kool-Tab Type MP resistors are a compact way to get a noninductive, high-power resistor into a limited space. The resistors are available in standard 1% values from 10 Ω to 1 kΩ.

I have used Caddock resistors in some extremely unfriendly applications and have found that they are very high quality (these resistors have passed an artificial lightning test without a hitch). To get a copy of the Type MP datasheet, or the entire Caddock catalog, write: Caddock Electronics, Inc, Applications Engineering, 1717 Chicago Ave, Riverside, CA 92507, tel 1-714-788-1700.

Aromat Photo-MOS Relays

Photo-MOS relays, which combine solid-state and electromechanical relay technologies, are available from Aromat Corp. These relays are quite small, come in 6-pin DIPs, and can control 150-mA loads at up to 400 V. Isolation of the relays is specified at 1500 V ac.

The relays use an optoelectronic device to drive a power MOSFET. The optoelectronic element converts received light to a voltage that turns on the MOSFET switching the load. This technique eliminates the need for a separate relay power supply. Information on this part is available from Aromat Corporation, 629 Central Ave, New Providence, NJ 07974.

RF Power Amplifier Modules

Philips has introduced a pair of new power amplifiers that are aimed at the cellular phone market, but are perfect for 70-cm amateur use. The BGY49A and BGY49B will give 20 watts output for 150 mW of drive. They operate from 12.5 V dc (nominal).

The BGY49A operates from 400 to 440 MHz; the BGY49B from 440 to 470 MHz. Both modules measure 2 × 0.75 × 0.32 inches. I don't know whether these power modules are available in the United States yet. Technical data on these modules is available by writing the Philips Components Division, Box 523, 5600 AM Eindhoven, The Netherlands.

Columns like this run on mail, so please drop me a line at the address listed at the head of this column. I'm always interested in knowing what types of components you would like to see listed in future columns.

Correspondence

Microsatellites on the Way

A consortium of Amateur Radio groups and a Utah college have teamed up to construct and launch a new class of ultra-compact "microsatellites" (See Fig 1). Project officials say these satellites are so small they can be launched on virtually any launcher.

Three AMSAT organizations, AMSAT-NA, AMSAT-LU and BRAMSAT (Brazil AMSAT) have joined with the Center for Aerospace Technology (CAST) at Weber State College, Ogden, Utah, to produce four satellites. TAPR, the Tucson Amateur Packet Radio organization, is providing financial support, and the ARRL is assisting with design and construction.

Each satellite consists of a common design bus. Each bus carries a mission-specific payload. AMSAT-NA and AMSAT-LU payloads are packet radio transponders. BRAMSAT's payload is a synthesized-voice transmitter for easily heard VHF FM downlinks. The CAST payload is an earth-looking CCD camera.

The most unique characteristic of each satellite is its volume and mass. Only 9 inches (23 cm) on a side, each cubical spacecraft will weigh less than 10 kg (22 lbs). The small mass and volume make it feasible to launch these spacecraft inexpensively, using launch vehicle accommodations that might otherwise be wasted.

The spacecraft are seen as pioneering a new class of payload analogous to NASA's Shuttle Getaway Special canister (GAS can), only smaller. GAS cans are capable of carrying several hundred pounds.

AMSAT forecasts a growing demand for small, low-cost communications satellites. This is an area in which AMSAT has worked for 20 years, preparing and launching OSCARs (Orbiting Satellite Carrying Amateur Radio) 5 through 13.

These new "tiny" satellites can fit where larger ones cannot; thus, many more near-term launch opportunities are available. While a major payload weighing a ton might have to wait five years or more to obtain a launch, the new microsats can be fitted into tight spots and launched on rockets which, at least in theory, have been fully booked for years.

The partnership of AMSAT-NA, AMSAT-LU, BRAMSAT and CAST allows each partner the benefit of a common bus structure. This amortizes much of the R&D throughout these spacecraft, while permitting each partner to tailor the payload to a specific mission.

According to AMSAT officials, this new class of satellite makes use of advances in microminiaturization, advanced RF devices and modular construction to push new performance, mass and volume frontiers for satellites. Several design reviews have already taken place on the four satellites. Construction has begun and initial testing is planned for early autumn.

Construction is being accomplished in a facility in Boulder, Colorado, under the leadership of Jan King, W3GEY. Design activities are carried out on Boulder and several other locations in the United States and Canada.

AMSAT-NA has contracted for an early 1989 launch for the first four satellites. These satellites will be launched into a polar, low earth orbit by Arianspace. The primary launch payload will be a French SPOT-II mission. *—Vern "Rip" Riportella, WA2LQQ, PO Box 27, Washington, DC 20044.*

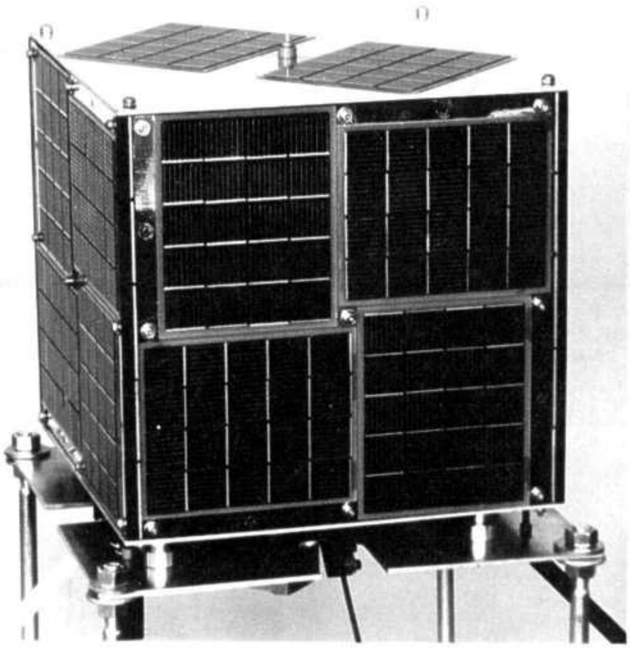


Fig 1—AMSAT's "microsat" satellite. The compact-cubical shape and efficient system design will allow more space-available launch opportunities.

The Angry Sun

Between June 23 and June 30, the sun went on the first real rampage of the new solar cycle. Over this period, five major flares were monitored using X-ray sensors on the GOES weather satellites. In addition, 27 moderate X-ray outbursts and approximately 72 subflares were measured.

Figs 2 and 3 show the GOES 1- to 8-angstrom X-ray flux for June 23 and June 24, where four major (class X) events occurred (0900 and 1800 UTC on the 23rd, and 0400 and 1600 UTC on the 24th). Flares of this magnitude will cause radio blackouts on paths in the sunlit hemisphere. These blackouts can last from minutes to hours, with the lower frequencies (14 MHz) affected the most, and the higher frequencies (28 MHz) affected the least.

One of the moderate flares that occurred on June 26 lasted 12 hours before it returned to preevent levels. Sustained periods of activity, such as that experienced in June, cause increased D-layer absorption weakening lower-frequency signals, even at night, and especially at high altitudes.

So far, this new solar cycle has not behaved in a normal manner. It appears to be headed to higher levels than first thought. If the activities of late June are any indication of what to expect, the solar cycle may also be more active than expected, making for some exciting propagation conditions. *—Bob Rose, K6GKU, ARRL Technical Advisor, 1242 Cresthill Rd, El Cajon, CA 92021*

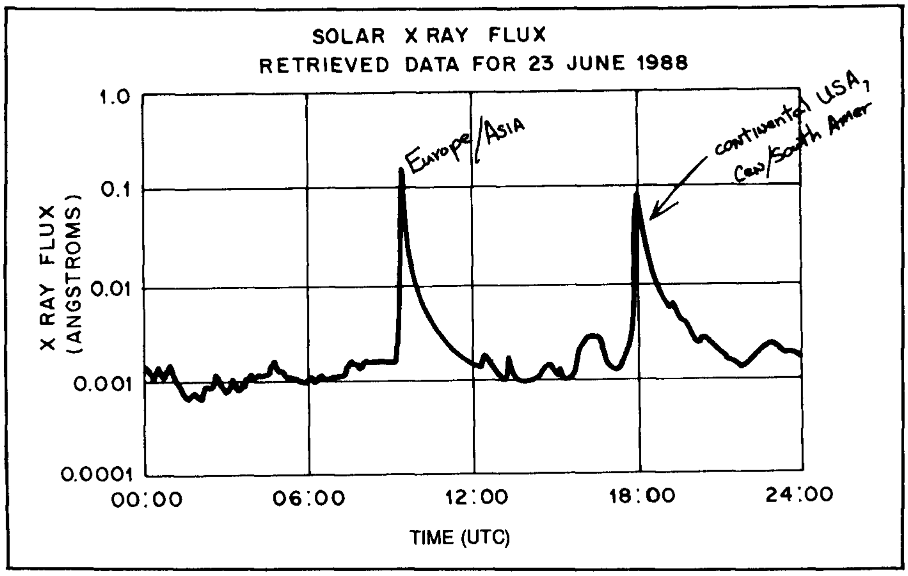


Fig 2—The June 23, 1988, solar flares as recorded by the GOES weather satellites. The continents most affected by the flares are listed on the charts.

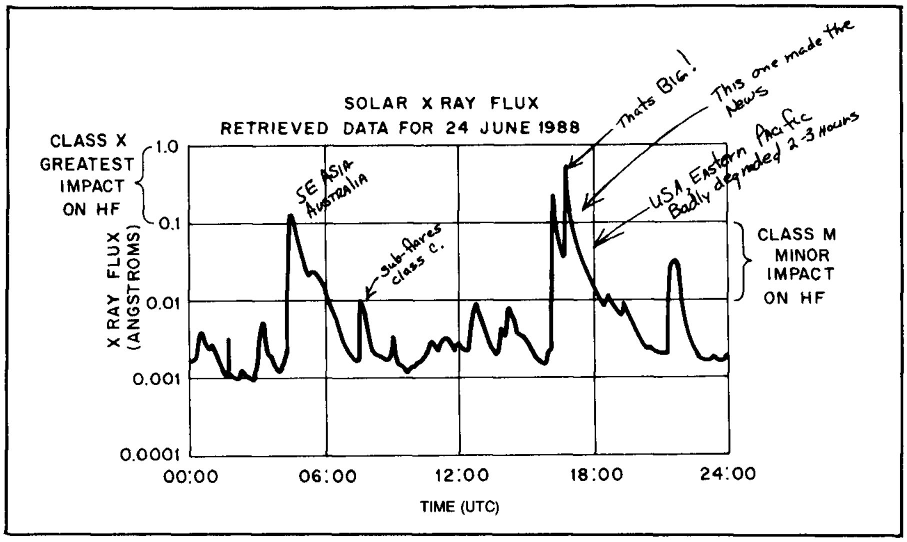


Fig 3—The June 24, 1988, solar flares. These two flares were much higher in intensity than the previous day's events. General solar activity was also higher than that recorded on June 24th.

Bits

Window Glass Tester For Mobile Antenna Compatibility

The Antenna Specialists Co offers an inexpensive, easy-to-use test instrument that permits a quick pre-evaluation of automobile window glass for properties that might impair the performance of On-Glass® or any other glass-mounted mobile communications antennas. The KAV 850 Window Test Kit determines in a matter of seconds whether or not a specific automobile window—with hiddne metallic tinting films, owner-applied tinting kits or defrosters—could substantially affect antenna performance. The tester also indicates optimum positioning of the On-Glass mounting foot between defroster wires. The window-glass tester can be used with any inexpensive hand-held digital capacitance meter capable of measuring capacitance values as low as 1 pF with a 0.1-pF resolution.

The kit includes a capacitance pickup/probe, cable harness and pickup wire for grounding. For further information, contact The Antenna Specialists Co, 30500 Bruce Industrial Pkwy, Cleveland, OH 44139-3996, tel 216-349-8683. —*Paul K. Pagel, N1FB*

EIA Committee Roster

The Electronic Industries Association has released a roster of Engineering Committees in booklet format. The booklet contains the names, industry affiliation and telephone numbers of EIA Engineering Committee members. It also has a list of current EIA staff members and a chart detailing EIA committee organization. To obtain a copy of this roster, contact the Electronic Industries Association, 1722 Eye Street, Northwest, Washington, District of Columbia 20006. —*Tom Francis, NM1Q*

New Audio Engineers Handbook

McGraw-Hill has announced the availability of the Audio Engineers Handbook. The *Handbook* contains information for engineers and experimenters who design, maintain or operate audio equipment. *Handbook* readers will find information and extensive discussions on the audio spectrum, digital and analog signal processing, digital and analog noise reduction techniques and studio broadcasting and recording. Industry standards and recommended practices are also presented in detail. The Audio Engineers Handbook is available from McGraw-Hill Book Company, 11 West 19th Street, New York, NY 10011, 800-262-4729. Price class, $79.95. —*Tom Francis, NM1Q*

Lightweight Wind Generator For Emergency Power

Amateur Radio operators are always interested in emergency sources of electrical power. The LVM-3 is a lightweight (13½ pounds), compact wind generator for use in charging 12/24 V lead-acid batteries. The LVM-3, designed to operate at moderate wind speeds, will begin charging with 5 mi/h and will produce 4 A at 22 mi/h. This wind generator comes with a 30-inch diameter, fiberglass-reinforced polypropylene fan (the mast is separate). A shunt regulator is available to prevent battery overcharging. The suggested retail price for the LVM-3 is $1,098. For further information, contact LVM/Bradely & Associates Marketing, 5147 South Harvard, Suite 123, Tulsa, OK 74135. —*Tom Francis, NM1Q*

8052AH-BASIC Micro Project Controller
(continued from page 9)

Table 3—Parts Suppliers

ICs	*LCD Module*
JAMECO® Electronics 1355 Shoreway Road Belmont, CA 94002 415-592-8097	Densitron Corp 2540 W 237th Street Torrance, CA 90505 213-530-3530
	Keypad
JDR Microdevices 110 Knowles Drive Los Gatos, CA 95030 408-866-6200	MASCO 7441 Lincoln Way Garden Grove, CA 92641 714-529-0866

Although this technique is fine for the channelized nature of operation on VHF/UHF, for HF I feel it goes too far in accommodating the microprocessor at my expense. For the "low bands," I'm old-fashioned enough to want to preserve the feel of the first analog receiver I used. This system may be several layers away from a variable capacitance in a tuned circuit, but the computer should humor me into thinking otherwise. (If you have a better idea for frequency tuning—it should also be inexpensive—I would like to hear from you.) Regardless of whether or not the RCU is for you, I hope that the I/O circuitry can be used in projects of your own.

Table 4—The WM6H CW keyer program.

```
1     REM CW KEYER PROGRAM
4     STRING 400,13
5     XTAL=12000000
14    $(1)="   MPC  KEYER"
16    $(2)="WM6H    "
100   REM KEYER PGM
105   XBY(0C000H)=87H:XBY(0C000H)=0D7H
110   EL=20000
115   REM READ PADDLE MEMORIES
117   DIT=XBY(0C000H).AND.80H
120   IF DIT>0H THEN GOTO 140
122   REM OUTPUT DIT
125   XBY(0C000H)=77H
127   PWM EL,EL,1
129   XBY(0C000H)=0D7H
134   REM AUTOSPACE
135   PWM EL,EL,1
136   XBY(0C000H)=97H:XBY(0C000H)=0D7H
137   REM STRUCTURE GIVES IAMBICITY
140   DAH=XBY(0C000H).AND.40H
150   IF DAH > 0H THEN GOTO 117
152   REM OUTPUT DAH
153   XBY(0C000H)=77H
154   PWM EL,EL,3
155   XBY(0C000H)=0D7H
160   PWM EL,EL,1
165   XBY(0C000H)=0C7H:XBY(0C000H)=0D7H
175   GOTO 117
500   REM DISPLAY MESSAGE ROUTINE
505   FOR I=0 TO 12:PUSH I:PUSH ASC($(1),I+1):GOSUB 360
510   NEXT I
515   RETURN
600   REM DISPLAY MYCALL ROUTINE
```

Future Projects

The biggest use I have for my MPC is freeing time on my personal computer. Right now I can't run a satellite orbit prediction program at the same time I'm running my packet radio terminal program. I've found multitasking operating systems to be a compromise on my computer, so I have to look elsewhere for a solution. For me, the answer will be to build some simple dedicated hardware around the MPC and then to translate public-domain BASIC programs to run on it. I hope you'll consider this solution as well. The MPC is simple to build, fun and easy to use. Put it in charge of your next project.

Notes

[1]S. Ciarcia, "Build the Basic-52 Computer/Controller," *BYTE*, Aug 1985, pp 105-117.
[2]MCS™ *BASIC-52 User's Manual*, Intel Literature Sales, PO Box 58130 Santa Clara, CA 95052-8130, 1-800-548-4725. Price class, $15.
[3]A copy of the basic operating program for the MPC described in this article is available from the ARRL Technical Department. Request the 8052AH-BASIC/MPC operating program.
[4]R. J. Halprin, ed., *The ARRL Operating Manual* (Newington: ARRL, 1987), p 4-5.
[5]*Microcontroller Data Book*, Intel Literature Sales, PO Box 58130 Santa Clara, CA 95052-8130, 1-800-548-4725. Price Class, $25.