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MAY 1989

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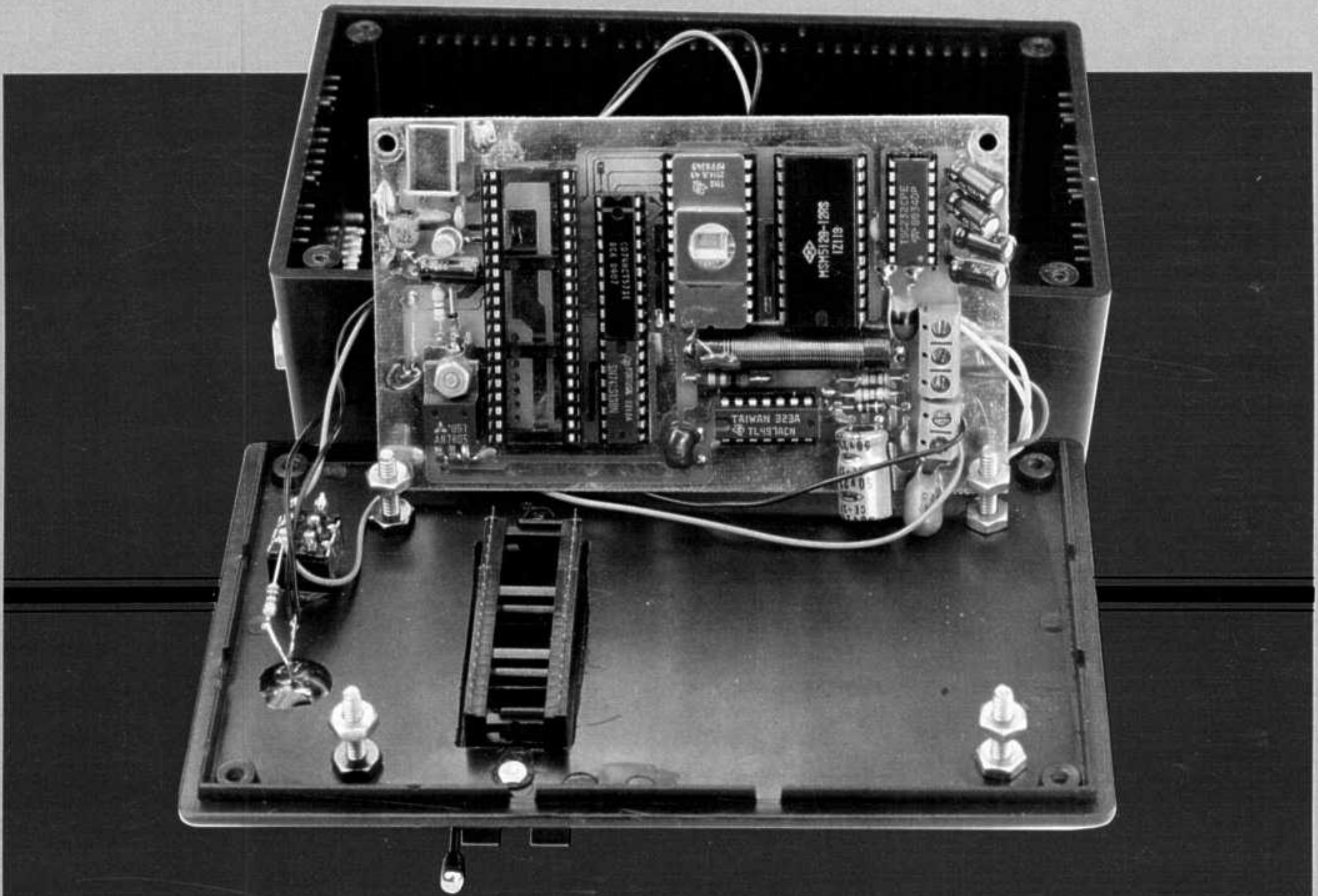

Oscarson MC68701 Programming Board

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Offices
225 Main St, Newington, CT 06111 USA
Telephone: 203-666-1541
Telex: 650215-5052 MCI
Electronic Mail: MCI MAIL ID:215-5052
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A picture of the MC68701 Programming Board's printed-circuit board and cabinet. Note that the underside of the ZIF socket on the front panel plugs into the socket on the PC board. More details inside this issue.

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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.

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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 06111 USA. 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 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. . .

Documenting Contributions

In any job in the workplace, it is worthwhile to pause and ask not only what is done everyday but what caused the job to be created. Then, pretend that the position doesn't exist and ask yourself (a) whether you would create it based on today's or anticipated needs, and if so (b) would it be different than the existing one. That's kind of brutal, isn't it? Nevertheless, that sort of exercise is part of managing a business, and it's necessary for staying lean and mean.

Now try that on Amateur Radio. Others who would have our precious slots in the radio spectrum are looking us over with lust in their hearts. Sure, we have idle chatter on the more popular bands, and there is a tendency to be a bit self-conscious about it when contemplating the worth of the spectrum. The commercial guys, of course, would like to have our frequencies so those kilohertz could be used to transmit chit-chat for financial gain! My point, is that we shouldn't be so embarassed about two citizens having a private conversation with low information content over ham radio. That's done in great gobs on the public switched telephone network—another spectrum user—and actually encouraged outside of work hours. Who would question the social value of calling "Mom" on Mother's Day?

But there's a more serious side to Amateur Radio. Just let your fingers romp through Part 97 of the FCC rules sometime. Paragraph (b) of Section 97.1, Basis and Purpose, gives the following as a fundamental purpose of Amateur Radio:

> Continuation and extension of the amateur's proven ability to contribute to the advancement of the radio art.

Hams have contributed to the state-of-the-art in a number of ways over the years. Radiotelescope, slow-scan television, single-sideband radio, packet radio, radio-propagation research, upward extension of the useful radio-frequency spectrum, linear-amplifier technology, and small-satellite development are prominent examples.

It is important that we not only continue our contributions to the state-of-the-art but that we document them—and not just to other hams. The ARRL *Repeater Directory* was sufficient documentation for the FCC to appreciate the number and distribution of repeaters in the various VHF/UHF bands. It is easy to see the occupancy between 222 and 225 MHz, for example. The usage of the 220-222 MHz portion of the band was largely undocumented because of the need to protect the privacy of the repeater telecommand frequencies above 220.5 MHz. High-speed packet was just emerging, and the other experimental uses didn't lend themselves to the same kind of documentation possible for repeaters. We need to take time to document our experimental activities so that the FCC and other spectrum users can appreciate the spectrum occupancy and significance of the experimentation taking place.

Probably one of the underdocumented fields is propagation research. Hams have discovered new modes of propagation, and these have been recorded in various journals. Nevertheless, we have acquired lots of hands-on operating experience that never gets reflected back into the propagation mathematical models. What is common knowledge among experienced hams about the behavior of certain frequencies over various paths and at certain times is not recorded, analyzed and packaged in forms useful to others. Other radio services do not have the luxury of trained and experienced radio operators. They are turning to adaptive systems with automatic link establishment (ALE) to replace the operator. Try designing one of those systems without intimate knowledge of what useful functions an operator performs. Vital to such designs are the following: (a) the best probabilistic model of how radio circuits should work, (b) a way of testing the circuit to see if it's working the way the model said it would, and (c) what to do if (a) and (b) fail. A good engineer can make such a system work. A good operator can make it work efficiently. A good engineer knowing what a good operator knows can design systems that work while optimizing spectrum efficiency. This is clearly a field to which we can contribute know-how by documenting what we've learned. It has been said that a genius is the first person to write down what everyone else knows.

Go forth and document.—W4RI

MC68701 Programming Board

By Edward Oscarson, WA1TWX
70 Behrens Road
New Hartford, CT 06057

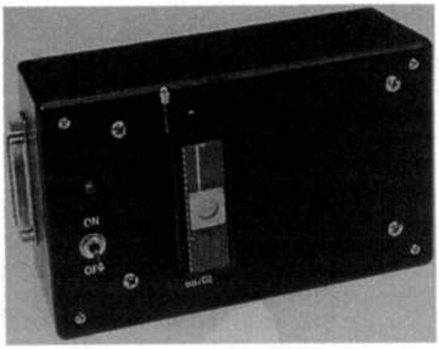
There are many single-chip microprocessors becoming available today at low cost. One of the least expensive (typically $9.95 to $14.95) of these is the Motorola MC68701. It is an 8-bit microprocessor (enhanced 6800 instruction set) with 2 kbytes of EPROM, 128 bytes of RAM, 3 parallel ports, a serial port and a 16-bit timer with compare register. The part even contains the programming voltage switching circuitry. A recent article in *QST* ("A Talking Wattmeter") uses the MC68701 for the controller. I also have a program that converts the MC6801-based Coleco Adam keyboard into a Morse code keyer by replacing the MC6801 with a MC68701 programmed for Morse code.

I have been using the 68701 and its less-powerful cousin, the 68705, for some time now. So far I have created Morse code keyboards, repeater controllers, transceiver controllers, and a generator monitor. All of the units require very few external parts since most of what is needed is already in the single-chip computer. Of course, in order to use the single-chip computer, it must be programmed. This is where most hackers get left out in the cold.

Motorola provides the schematic and software listing for a programming board for the MC68701 in application note AN-832, "Letting the MC68701 Program Itself." The programming board can copy the contents of a programmed 2716 EPROM into the MC68701. The board uses few parts and is relatively simple to build, but it also requires a 26-V power supply which is not too easy to come by. There are also problems with the EPROM copy approach to programming if you are using an IBM® PC for development.

When I started using the Motorola processors I was using a MC6809-based development system. Its built-in EPROM programmer had no problem burning 2716s from the output of my 6801 cross assembler. I now use an IBM PC for all my development work, and that is where the glitch got into the system. The cross assembler output was not compatible with my inexpensive PROM programmer.

There are many inexpensive (under $100) cross assemblers available for the MC68XX series processors. Some of them are even available as *shareware* (try first then register if you like it) or public-domain software on many bulletin-board systems or through the mail. All of the Motorola cross assemblers that I have seen for the PC produce output in Motorola S-Record format (Fig 1). This format is not compatible with most of the inexpensive EPROM programmers available for the PC. Also, the thought of having to program two devices (EPROM and micro) to get one never appealed to me.



Front panel showing micro processor.

The object code format incompatibility could have been cured by writing a translator program on the PC to convert the Motorola S-Records to the Intel hex format supported by the EPROM programmers. This still leaves the two-step programming process which is a pain in the neck, especially during program development. Since I had to write some software with either approach, I opted to use the one I was most familiar with and fired up my MC6809 system for one more program.

The programmer described here is an upgrade to the Motorola programming board. I have enabled the on-chip UART, and added a RAM to the design. The 26-V power supply was constructed using inexpensive and readily available discrete components. The programming software was rewritten to include download software that allows the S-Records to be transferred to the board by most communications programs available on the PC. The file can even be "printed" to the programming board over the serial port if a communications program is not available. For more advanced users, small routines can be run in RAM to test programs before they are put together in the PROM.

The cost is kept down by using the MC68701 that is being programmed as the controller for the board during upload and download operations. A manual-memory load feature is also provided that allows programs to be entered in hex using only a terminal.

The programming board consists of a 2-kbyte EPROM, 2-kbyte RAM, RS-232-C buffers, and the 5-V and 26-V power supplies. A 12-V dc wall transformer powers the board. The MC68701 to be programmed is set into a zero-insertion-force (ZIF) socket. At power up, the MC68701 is reset to mode 0, the programming mode, by connecting P20-P22 to ground (this is in artwork on the board). When P20-P22 are grounded at power up, the reset vector is set to BFFE, the highest address in the external EPROM. This location contains the starting address of the programmer software. When the reset signal goes high, the processor fetches the address of the start of the program from BFFE and starts execution at that location.

When in programming mode, the MC68701 has a total address space of 64 kbytes. Some of that address space is occupied by the internal EPROM, RAM, and I/O ports; the rest is available outside the part. Two of the I/O ports on the chip are disabled in this mode and are used for address and data I/O. The lower 8 bits of the address bus are multiplexed on the data port so that the third I/O port can still be used.

A 74ALS573 is used to latch the lower 8 bits of the memory address from port 3.

```
S113F8000000D2AAE8D1A2DEADED00A8F3E1EAA996
S113F810BFBEBCB8B0A0A1A3A7AFC7D5B1FF00CCF1
S113F82000428185612084638040 8E658243416704
S113F830868B626021648866898D83ED00ED00000BS9
```

Fig 1—Motorola S-Record Data Format

The ALS573 is similar to an LS373 except that the inputs and outputs are on opposite sides of the chip to simplify PC board layout. The upper address bits are available on port 4. A 74LS138 decodes the upper 3 address lines to provide chip selects for the EPROM and RAM. The data bus is enabled onto port 3 by the processor after the address is latched. The E (enable clock) clock is used to gate the data onto the bus and into the external devices.

System timing is derived from a 4.914-MHz crystal and an oscillator internal to the MC68701. The oscillator output is divided by 4 to produce the E clock which is used to define the basic memory operation cycle time (1.2288 MHz). The E clock is also divided internally to provide the baud-rate clock to the UART. The board can be set to either 9600 or 1200 bauds. Port 1 bit 7 is the baud-rate select input. A low level selects 9600 bauds (the board artwork selects 9600 bauds and must be cut, and the input tied to 5 V if 1200 bauds is desired).

The programming pulse timing is derived from the internal timer. The timer compare register is loaded with the present timer count plus the number of clock cycles required for the pulse width. The compare status is then polled to determine when the timer catches up to the compare value. The timer is polled by the software rather than interrupt driven in order to keep the design simple. The programming code is similar to the program described in the Motorola data sheet. The Motorola program has been modified only slightly to interface with the new crystal frequency and the download capability of the rest of the program.

The communications interface provided by this programmer is very simple. Only the data lines are supported, no control signals. I find that the PC and programmer can easily keep up with a steady 9600-baud data rate for the duration of a 2-kbyte download or upload session without the need for any of the usual RS-232-C control signals. The omission of these control signals simplifies both the hardware and software designs.

The data must be downloaded to the on board RAM prior to the programming of the MC68701. Those users who wish to put an EEPROM in place of the static RAM may do so and get the ability to program multiple MC68701s without having to download to each one. An X2816 from XICOR can be used as the RAM replacement. The longer write cycle time of the X2816 (10 ms) will require the use of a lower baud rate. A baud rate of 1200 should be adequate since each of the two characters that form the byte would take about 8 ms (for a total of 16 ms per byte). This would result in a longer time for the initial load, but only programming time for the successive chips.

The programmer requires a 9 V to 12 V power supply. The Radio Shack® 9 V, 1-amp wall supply works fine. A TL497 switching regulator operating in step-up mode is used to generate the programming voltage. It is set to 26 V and can easily supply the 50 mA required for programming the MC68701. The 26 V dc is applied to the MC68701 reset pin through a 2N2222 transistor. The resistor and capacitor connected to the base of the transistor form the reset delay circuit. The Zener diode connected to the base forms a voltage regulator with the 2N2222 that keeps the voltage at the MC68701 reset pin between 20 and 22 volts. The MC68701 can operate (run programs) with the reset pin at 21.5 V or 5 V.

The 5-volt supply is generated by an LM7805. It is decoupled by 0.1μF capacitors and is powered from the 9 V dc input to the board. All of the logic on the board is powered from this supply. The board power consumption is about 300 mA, so the regulator is mounted to the board to help it stay cool.

The TTL signals from the MC68701 UART are converted to RS-232-C levels by a LT1081 RS-232-C transceiver. This part contains a pair of voltage level converters that generate ± 9 volts from the 5-volt supply. Its current draw from the 5 V is typically 20 mA, making the part an excellent replacement for the more common MC1488/MC1489 RS-232-C driver and receiver chips. The LT1081 has two transmit and two receive buffers, but only one of each is used. The board has a hole pattern that will accommodate the LT1083, LT1081, and MAX232. The MAX232 and LT1081 chips are pin compatible with the LT1083 if plugged into the bottom part of the LT1083's socket. (The LT1083 is an 18-pin device, the other two are 16 pins). Pin 18 on the LT1083 is an enable, pin 1 is not used. The MAX232 and LT1081 have no enable pin therefore fit in a 16 pin package. The 1-μF capacitors (4) used with the LT1083/LT1081 must be changed to 22 μF if the MAX232 chip is used.

Programs written for the MC68701 must be assembled to reside between F800 and FFFF (MC68701 internal EPROM). The download software translates the program address as it is downloaded to that of the external RAM (8800-8FFF). The programming software then copies the RAM contents at 8000-8FFF to the on chip EPROM at F800-FFFF. Other routines allow the EPROM contents to be sent back to the host computer and the editing of RAM memory. (NOTE: The MC68701 P20-P22 I/O port bits must be tied to 5 V during reset to have the processor start execution in the internal EPROM.)

This programmer has been an invaluable tool in the development of the controller for many of my ham radio projects. I hope it works as well for you.

Table 1—Programmer Command Set

D—DOWNLOAD S-RECORD DATA TO RAM
P—PROGRAM THE MC68701 FROM RAM
E—CHECK IF THE MC68701 IS ERASED
V—VERIFY MC68701 PROM AGAINST RAM
U—UPLOAD MC68701 DATA TO HOST
R—COPY MC68701 DATA TO RAM
M—MEMORY EXAMINE/CHANGE
T—TEST AND CLEAR PROGRAMMER RAM
L—DIRECT LOAD TO RAM
J—JUMP TO ADDRESS (RUN A PROGRAM)

PROGRAMMER OPERATION

Operation of the programming board is very simple. Before applying power, connect the board to a serial port on the PC. The board's RS-232-C connector is set up as if the board were a modem. Before turning on the power, plug an erased MC68701 into the ZIF socket.

WARNING:
NEVER INSERT OR REMOVE A MC68701 WITH THE POWER ON

The PC communication program should set the IBM PC serial port to 9600 bauds, no parity. When power is applied to the programmer, the programmer will then send the ON LINE message to the PC. At this time, the user may enter any of the programmer commands. Table 1 is a list of the available commands. Commands are executed when the letter is sent to the programmer followed by the ENTER or CR character (the L, D, and M commands do not need the ENTER). Any character other than ENTER or CR stops execution of the command and returns control to the command interpreter.

At this point, the programmer expects to see an D downloaded from the PC to initiate the load operation. Any characters sent after the D are ignored unless they are valid S-Records. The user should then use the communications program to send the S-Record data file to the programmer. When the data transmission is completed, the programmer sends back the starting address of the last block of data that was sent followed by the message LOAD COMPLETED.

The download software will produce error messages for load addresses outside the F800-FFFF range, and for checksum errors. If these messages appear, there may be problems with the downloaded code. The out-of-range address can be corrected by changing the assembly source code to put the address in range. The checksum error is

Parts List for MC68701 Programmer

QTY	*PART #*	*Desig.*	*Description*
1	MC68701	U1	Microprocessor with EPROM
1	2716	U2	EPROM, PGM68701 V1.0
1	HM6116	U3	2-kbyte by 8-bit RAM
1	74ALS573	U4	Octal latch
1	74LS138	U5	3-to-8 decoder
1	TL497A	U6	Switching regulator
1	LT1080	U7	RS-232-C interface
1	LM7805	U8	5-V regulator
2	10 pF cap	C1,C2	
1	47 μF cap	C3	
3	0.1 μF cap	C4-C6	
1	10 μF cap	C7	
1	150 pF cap	C8	
4	1 μF cap	C9-C12	
2	22 μF cap	C13,C14	
1	1.5 kΩ	R1	
1	24 kΩ	R2	
1	1.0 Ω	R3	
1	1.2 kΩ	R4	
1	3.0 kΩ	R5	
1	1N5252B	VR1	24-V Zener diode
1	2N2222	Q1	NPN transistor
1	4.194 MHz XTAL	X1	
1	100 μH inductor	L1	

usually caused by a data file that has been changed either by the user or by a bad disk. Each piece of data is also checked against the RAM data as it is stored. If the RAM data does not match what was downloaded, an error is flagged. The RAM data checking is not done when at 1200 bauds due to the delay in the EEPROM write cycle.

The down load is terminated by a S-Record of S9 followed by a CR or ENTER. The S9 and CR may be entered manually (if file not being sent) to terminate the download.

The programming sequence is then started by sending a P to the programmer. The programmer then performs a blank check on the part to check for erasure. If erased, the part is programmed then verified. If not erased, the programmer will prompt the user for permission to attempt to overprogram the device. A Y or N from the PC will continue the sequence or terminate. Status messages are sent to the PC at the start and end of each step in the programming sequence.

The Motorola programming algorithm has been modified slightly so that it skips locations that contain zero (the EPROM erased state). This provides a faster programming time for small programs. The programmer also provides a status line while programming that displays the start address of the 256-byte block that is being programmed.

The erased condition check and verify sequence may be run by themselves by sending an E or V to the programmer from the PC. This provides the ability to check previously programmed devices against the downloaded code.

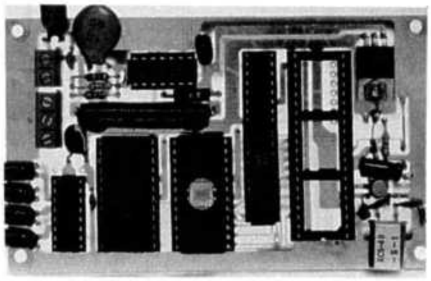
Data may be loaded directly to the RAM if it was assembled for the 8800-8FFF address space by sending a L followed by the data. The command operation is identical to the D command except that it does not translate the address. This allows programs to be loaded into RAM and tested. A G followed by a 4-digit hex address will transfer control to the program. The program should return control to the programmer by executing a jump to address B800 or with an RTS instruction.

The RAM memory test is initiated by sending a T to the programmer. A proceed/terminate message is sent back to the PC after which an answer of Y will test and clear the RAM. The RAM test is a address overlap test followed by four data pattern tests, leaving the RAM in the cleared (00) state.

An additional feature of this programmer is the ability to upload the contents of a programmed MC68701. A U followed by a 4-digit hex address sent from the PC will initiate the transmission of the EPROM contents The data format will be Motorola S-Records. The communication program running on the PC must be able to transfer data from the serial port to a file for this function to work correctly. The upload software will work only in the EPROM and RAM address range (8800-8FFF and F800-FFFF).

An R sent from the PC will cause the MC68701 EPROM contents to be transferred into RAM, but not to the PC. There is a 10-ms delay between each byte transferred when the programmer is set to 1200 bauds so that EEPROM may be used in place of the RAM.

The programmer also supports a memory examine/change command. An M followed by a 4-digit hex address will cause the board to display the contents of the specified address. The operator can then change the data by entering two hex digits, or can scroll forward and backwards in the memory without changing it. The enter key terminates the operation, "," and "." control the scroll forward and backward respectively.



Component side of the printed-circuit board.

Complete kits of parts and assembled units are available from:

Single Chip Solutions
PO Box 680
New Hartford, CT 06057

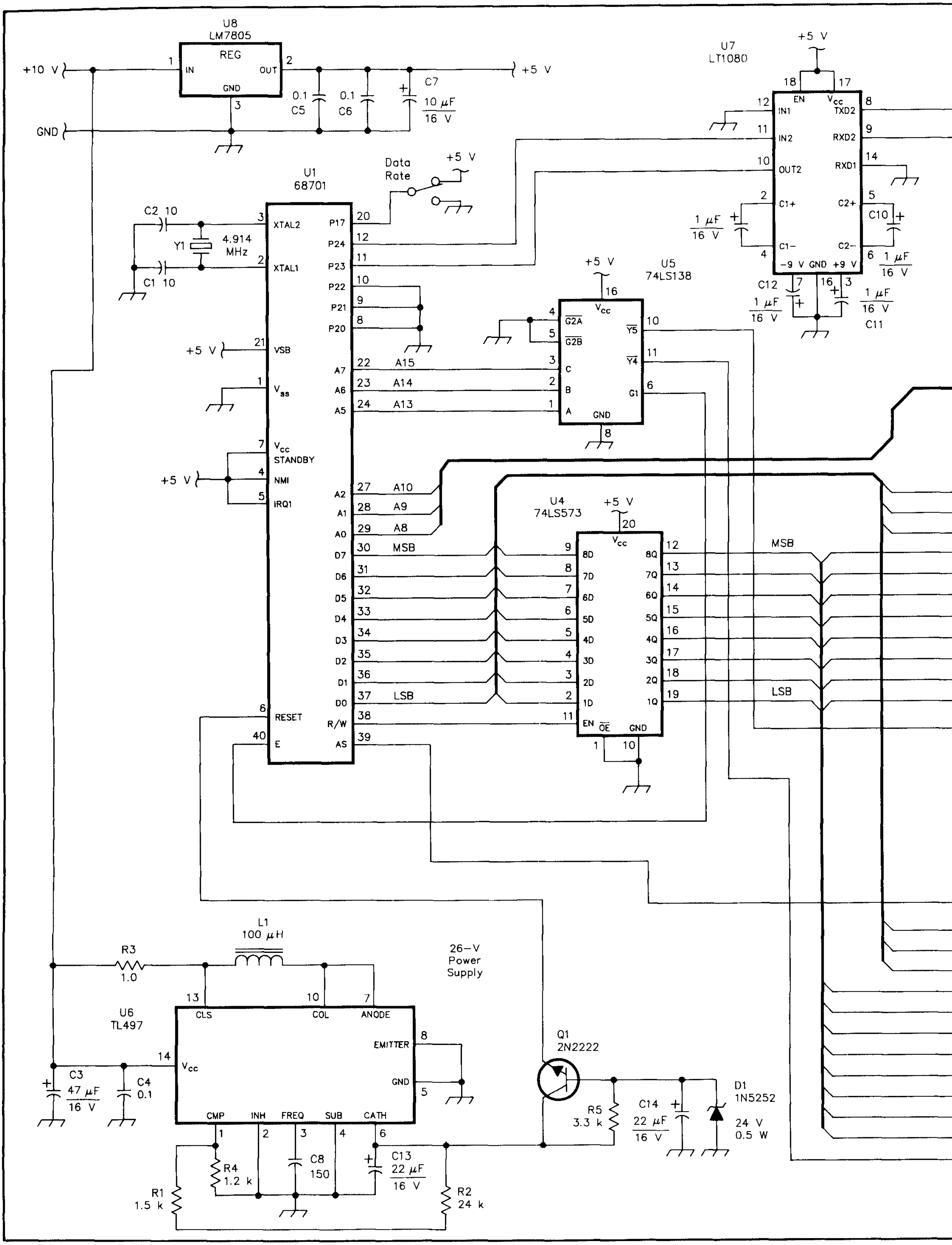
Kit (With 68701, wall transformer, manual, but no case)	$135
Assembled (With 68701, wall transformer, manual, but no case)	$150
Public Domain Cross Assembler for the PC (copy fee)	$5.00
Additional MC68701s	$19
Source code and instruction for Adam Morse code keyer	$40
Programmer Board	$40
PROM	$35

Add $3.50 for shipping/handling on Kit or Assy.
Add $2.50 for shipping/handling for 2716, disks.
CT residents add 7.5% sales tax.

Additional MC68701s may be obtained from:

Jameco Electronics
1355 Shoreway Rd
Belmont, CA 94002
tel 415-592-8097

American Design Components
62 Joseph St
Moonachie, NJ 07074
tel 800-524-0809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LM7805
REG
IN
OUT
GND
+10 V
GND
+5 V
0.1
C5
0.1
C6
C7
10 μF
16 V
U1
68701
Data
Rate
+5 V
C2 10
C1 10
Y1
4.914
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XTAL1
P17
P24
P23
P22
P21
P20
VSB
V_{ss}
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STANDBY
NMI
IRQ1
A7
A6
A5
A15
A14
A13
A2
A1
A0
A10
A9
A8
D7
D6
D5
D4
D3
D2
D1
D0
MSB
LSB
RESET
E
R/W
AS
U7
LT1080
EN
V_{cc}
IN1
IN2
OUT2
TXD2
RXD2
RXD1
C1+
C1−
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C2−
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16 V
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C11
C12
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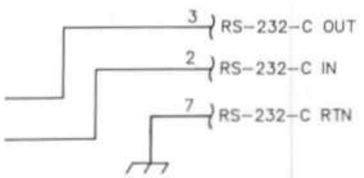
0.1
R4
1.2 k
R1
1.5 k
C8
150
C13
22 μF
16 V
R2
24 k
Q1
2N2222
R5
3.3 k
C14
22 μF
16 V
D1
1N5252
24 V
0.5 W



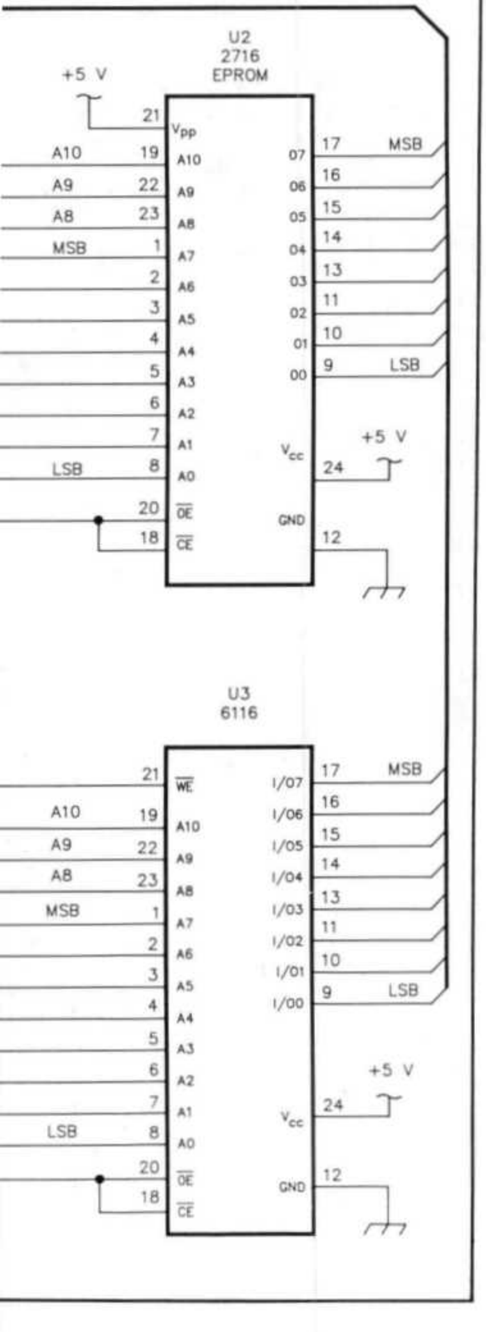
Except as indicated, decimal values of capacitance are in microfarads (μF); others are in picofarads (pF); resistances are in ohms; k=1000, M=1,000,000.

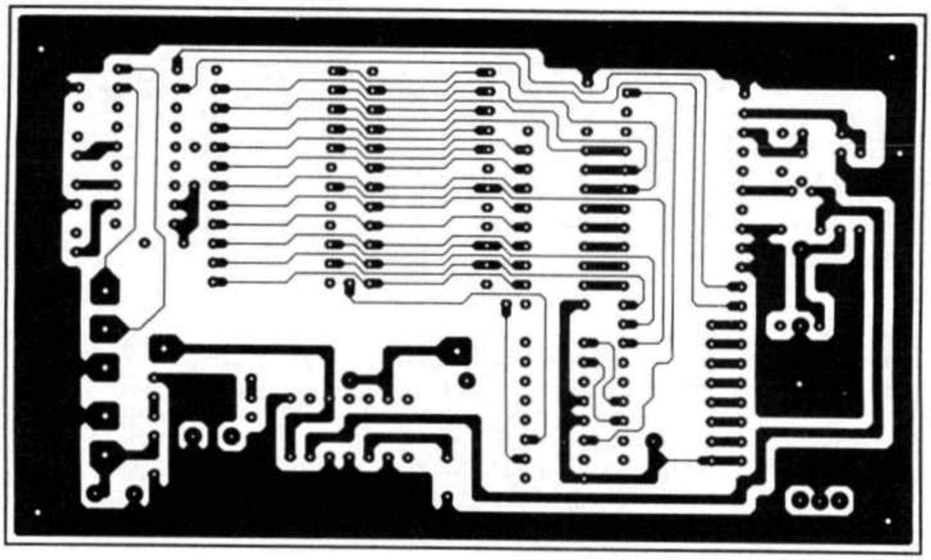
IC pins not shown are unused.

NOTES

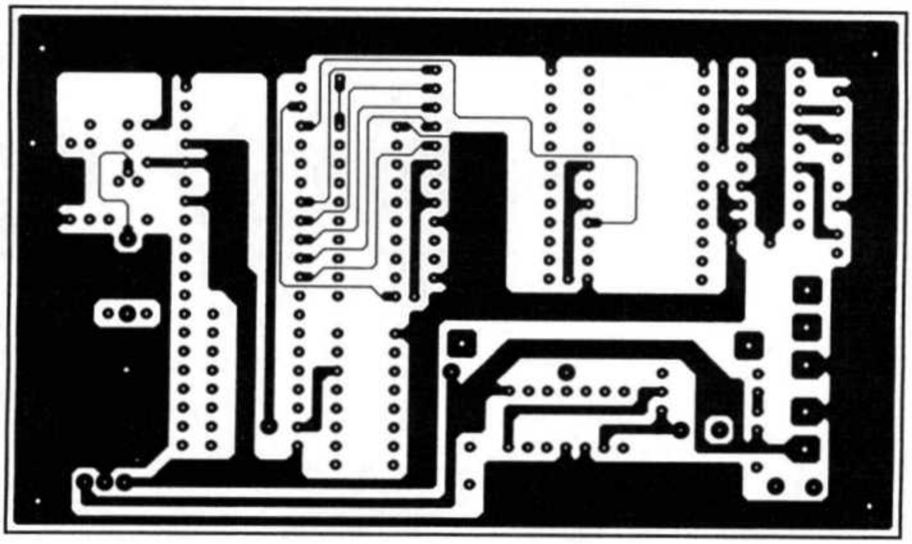
1: The LT1080 may be replaced with a MAX232 if C9–C12 are changed to 22 and it is plugged into holes 2–9 and 10–17 of the LT1080 socket.

2: Input power is 9 V DC –12 V DC, 300 mA

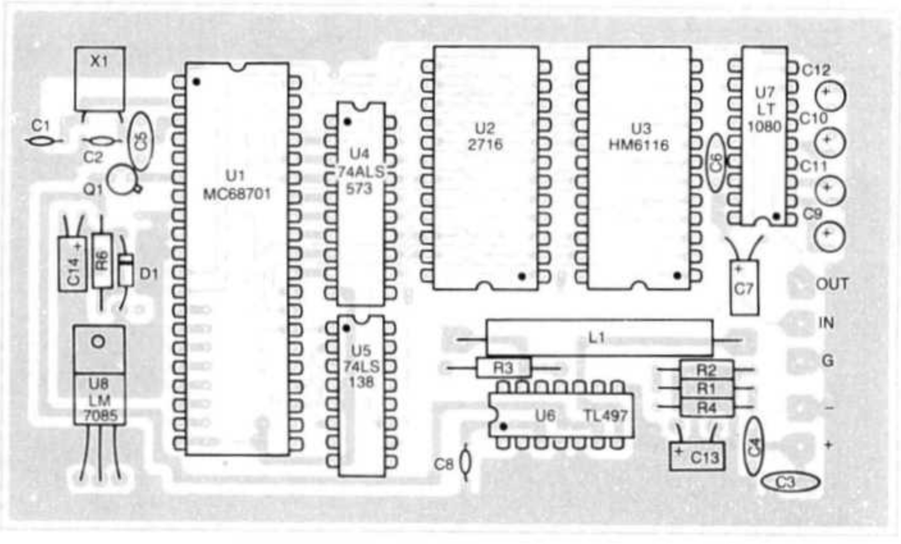




68701 Programmer solder side (mirror image, X-ray view).



68701 Programmer top layer component side



68701 Programmer assembly.

Receiver Front-End Protection

By Chuck Clark, AF8Z
4 N 560 Powis Rd
West Chicago, IL 60185

Protecting your shack and antenna-mounted preamps from lightning and RF radiated from other sources is of concern to most amateurs. I believe that many "lightning-damaged" preamplifiers are *not* damaged by lightning, but by RF radiated from other antennas on site. Luckily, most lightning-protection procedures you incorporate also help to protect antenna-mounted preamps from high levels of locally radiated RF.

The majority of GaAsFET preamplifier failures are caused primarily by the presence of excessive voltage at the gate-to-drain junction of the GaAsFET. To protect the transistor, the voltage transient must be clamped before the insulating layer of the transistor is punched through—a seemingly impossible task given the small, thin junctions of a GaAsFET.

Mast-mounted preamps have three destructive-energy entry points: the input (antenna), output (receiver) and power-supply ports. The input port is usually protected with a pair of parallel, reverse-connected diodes (D1 and D2 of Fig 1). Normally, this is the only port that is protected.

Radar receivers often use a PIN diode to protect the receiver front end. The desired diode characteristics are low loss when off, and fast attack times when turned on. These characteristics can be obtained with a single shunt-mounted diode with a dc return. At radar frequencies, this works well because the diode storage time is greater than the required conduction time for the reverse half cycle.

Diode Testing and Installation

I've tested the protection capabilities of several different types of diodes. The setup I used for the leakage tests consisted of a doubly balanced diode modulator for the pulse modulator, a wideband amplifier and a Tektronix 7104 oscilloscope. The oscilloscope has a 1-ns rise time, which is sufficient for these tests. (The typical amateur transmitter has a rise time of 33 ns or greater—30 MHz or less bandwidth).

You might expect that hot-carrier

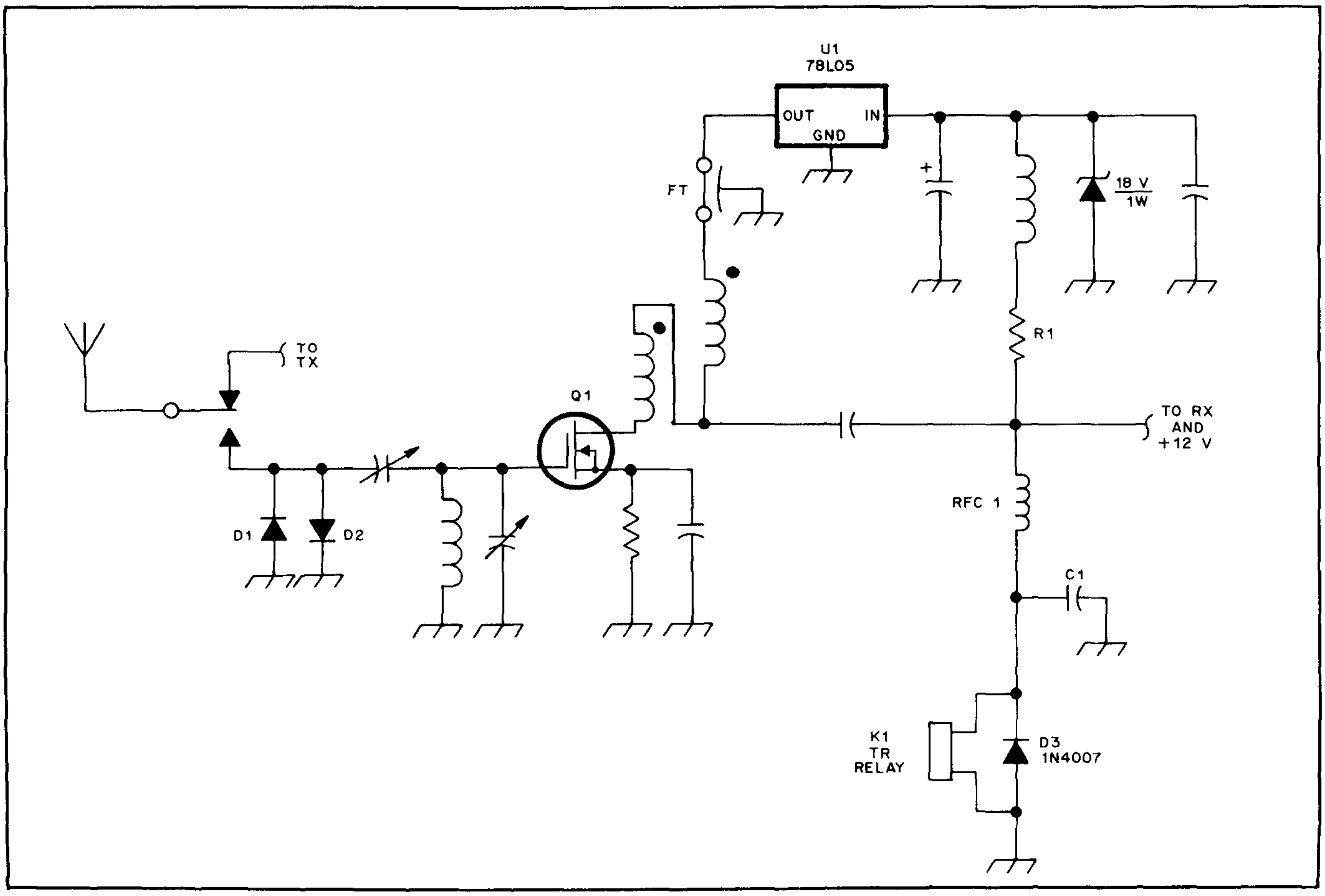


Fig 1—Basic schematic of a typcial VHF preamplifier showing transient-protection measures incorporated.

diodes would offer superior protection because of their fast switching times. Another seemingly apparent "advantage" of hot-carrier diodes is that their relatively low turn-on threshold voltage provides an additional margin of protection. However, diodes in the 5082-2800/1N5711 series do not exhibit the desired performance. It appears that the internal resistance of these diodes is great enough to prevent effective limiting. Their limiting knee is quite soft, and the peak voltage continues to rise with increasing input power. (I did not test a PIN diode with long enough storage time. Even the 5082-3188, which is commonly used for HF attenuators, showed rectification.)

The best place to mount the protection diode is at the preamp input; if placed across the top of a tank circuit, the diode losses have a greater effect upon the receive-system noise figure. This is because the higher transformed impedance of the device is then closer in value to the shunt resistance of the diode, and therefore carrying a more significant portion of the signal current. None of the diodes that I tested had an insertion loss greater than 0.1 dB, being typically 0.06 dB across 50 ohms (measured on an HP 8753).

One effect of diode limiting is its reduction of the receive-system intercept point. I was quite worried about this, living in suburban Chicago. The performance of the various limiters I tested is shown in Table 1. The third-order input-intercept point shown in the table is that of a preamp I built for the Central States VHF Conference in 1987.

Obviously, hot-carrier diodes will not protect against significant amounts of energy coupled into the input port during a lightning strike. But they don't have to. If a dc-grounded antenna is used, and the feed line is short, very little differential exists across the feed line. In fact, if the preamp is at the same height as the antenna, the voltage developed across the feed line should be nil. For most of us, this simply requires that we mount the preamp closer to the antenna.

Filtering As Protection

Another method of protecting the active device in the preamp is to use additional filtering (see Fig 2). Stretching the destructive pulse with a narrow bandpass filter reduces the pulse rise time and energy. See Table 2 for the results of comparing a single-resonator, 2-meter filter to a two-resonator filter, and their relative attenuation on different amateur bands.

Table 2

Preamp Rejection v Preselector-Tuned Circuits

	Attenuation (dB)	
Frequency (MHz)	*Single Resonator Filter*	*Dual Resonator Filter*
432	5.7	43
220	1.8	36
50	23.0	80
30	33.0	99
14	46.0	>99

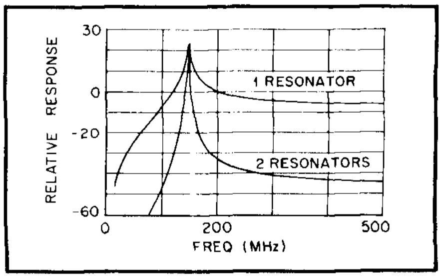


Fig 2—Stretching the destructive pulse with a narrow bandpass filter reduces the pulse rise time and energy. Here, the effect of one- and two-resonator filters is shown (see Table 2).

Additional attenuation of business-band and FM broadcast-band signals afforded by the additional filter section may solve other intermodulation problems as well. The best protection you can offer your preamp when you leave the shack is to disconnect the preamp input from the antenna (remember to terminate the preamp input). Place the antenna switch in the receive position. This way, the preamp's active devices are protected by an additional 50-70 dB of attenuation. This procedure will not, however, protect your preamp from your own transmitter while you're monitoring your own signal.

Power-Supply Protection

The power-supply port needs to be protected from two different sources: radiated RF and lightning transients. The probable cause of the radiated RF problem is your own station. To protect against radiated RF, enclose the preamp in an RF-tight box. Bypass the power line with a high-quality feedthrough capacitor or filter. (The capacitor should present a low reactance at the lowest frequency that is used at your station.) Use a choke to help attenuate any RF voltage that remains across the capacitor.

A common belief among amateurs is that a preamp and TR relay should not be powered from the same supply. This is not the case. With proper attention to detail, no problems should be encountered. If you can protect the power-supply output from lightning, can the back EMF from a relay be a problem? For added protection, powering the TR relay from the same source as the preamp ensures that the preamp is disconnected when the power is off at the station. Precautions that should be taken include: 1) Always use a diode across the TR relay coil (D3 in Fig 1); 2) use a dropping resistor (R1 of Fig 1) between the voltage regulator and the relay's bypass capacitor (C1). This will give the capacitor used to absorb the transient something to work against.

There should still be a minimum of 3-V drop at the regulator. For power supplies delivering 12 V and 10-15 mA of preamp current, a resistor value of 220 to 270 ohms for R1 should be enough for use with a 5-V regulator. Almost all of the transient filtering will come from the RC time constant—most regulator rejection falls above 1 kHz. Film capacitors work well in this application because their reactance remains low over a wide frequency range.

I measured the turn-off back EMF of a DK-60 relay as 250 V. To make things worse, the voltage rings back up to over 100 in the other direction. A 1N4007 diode can easily handle this voltage, as will a Zener diode of proper ratings. Var-

(continued on page 13)

Table 1

Front-End Protection-Diode Performance

Device	*Limiting level (Volts P-P)*	*1-dB Compression Point (dBm)*	*Preamp 3rd IP (dBm)*
1N5711	0.35	3.51	17.2
1N4148	0.9	9.06	17.6
MA 47122	0.9	9.48	17.3
MA 47089	0.8	11.37	17.7
5082-3188	0.55	8.96	17.6
MRF966 Preamp			-2.0

VHF$^+$ Technology

By Geoff Krauss, WA2GFP
16 Riviera Drive
Latham, NY 12110

State-of-the-Art above 1 GHz: Some Introductory Considerations

I know of several major multioperator VHF+ contest operations that are seriously thinking about putting a pair of "octopussed" stations on 2304 MHz and/or on 10 GHz. Each of the pair of stations on one band would be able to grab transmitting priority if the other station was not then transmitting. At least theoretically, two separate QSOs could be carried on in interleaved and semi-simultaneous manner without violating the one-transmitted-signal-per-band rule. This complicated setup is being necessitated because the rules can apparently be interpreted to allow a multiop to send out so-called "rovers". These rovers can be worked above 2.3 GHz as many times as possible, for full credit, as long as each new contact is in a different grid square. What may have started as a way to get more activity on some of our microwave bands has now degenerated into a situation where stations, other than the sponsoring multiop, usually not only do not work the rovers, but may not even be able to work the multiop station, as its microwave people have to use 100+% of their contest time in working their own rovers. The separately staffed, octopussed second station on each band now becomes needed to work other contest stations, so that the other stations can also get some microwave points and do not raise too much of a row about the self-working activity! (Something could perhaps be changed if we had a V/UHF Contest Advisory Committee, but with only about a dozen ARRL-sponsored VHF+ contests a year, we do not even have an ad hoc committee anymore.)

The point of the above comment is that assembling a simple CW station for 1+ GHz use has become relatively easy in the late 1980s. Almost any of the 'brick'-type local oscillator units with ham-band output frequency (as discussed in many of my previous columns of the last few years) can be modified for keying or, unmodified, make great drivers for keyed amplifiers. Power levels less than a watt work very well out to 50-80 miles, with small antennas and simple, single-conversion receivers (noise figure of 10 dB and an IF, say 5-6 MHz, so low as to guarantee lots of image noise). A slightly more sophisticated receiver will give state-of-the-art, close-to-theoretically ideal performance, all without the major metal-working tasks which used to be associated with almost all work (amateur *or* professional), above 1000 MHz. Before I consider what the state of the Amateur Radio art is on a particular 1+GHz band, we should review the basic definition and importance of each of the four receiver characteristics: sensitivity, selectivity, stability and spuriousity.

Sensitivity is the receiver's ability to distinguish desired .pa intelligence (a weak signal) from the surrounding undesired noise. While a good operator can hear and distinguish a CW signal at least 20 dB down in the noise, most sensitivity definitions use an input signal power P_{in} just equal to the input noise power P_n, so that $P_{sens} = P_{in} = P_n$. This input noise is due to thermally agitated, randomly moving electrons in the system antenna, lead-in cable, etc. If the front end of the receiving system were at a temperature of absolute zero ($-273.15°$ C = 0 K), then, by definition, all random motion has ceased among molecules, atoms and free subatomic particles. Free electrons would be "frozen" in place and not randomly moving through the equivalent resistance (R_0 - 50 ohms), and would not generate any thermal noise; the only noise output from the receiver would then be the noise coming into the antenna and any noise added by the receiver itself. Alas, it is impossible for even the well-equipped amateur to cool the station receiver *and* antenna to any temperature even closely approaching absolute zero. We just have to take into account the thermal noise present at the receiver input. This noise will increase as the temperature increases. The "temperature" of an object is actually a measure of the average heat, or thermal energy of that object. The higher the temperature, the higher the average heat energy and the faster and more energetically the electrons will move randomly around in the conductors and components of the system. The average noise power P_n is, it turns out, spread pretty uniformly across a very wide frequency range and forms a level "noise floor" (Fig 2) for the receiver. This input noise power thus depends only on the effective temperature T of the system front-end and the effective bandwidth B where k is Boltzmann's constant (1.38 x 10 exp − 23 joule ÷ K) which allows us to find the input noise power in watts, for temperature in K and bandwidth in Hz. The standard room temperature is taken to be 290 K (17° C), so that P_n is close to (-141 dBm + 10 log B (kHz)) for a room-temperature receiver. This equivalent receiver noise can be combined with the

(continued on page 14)

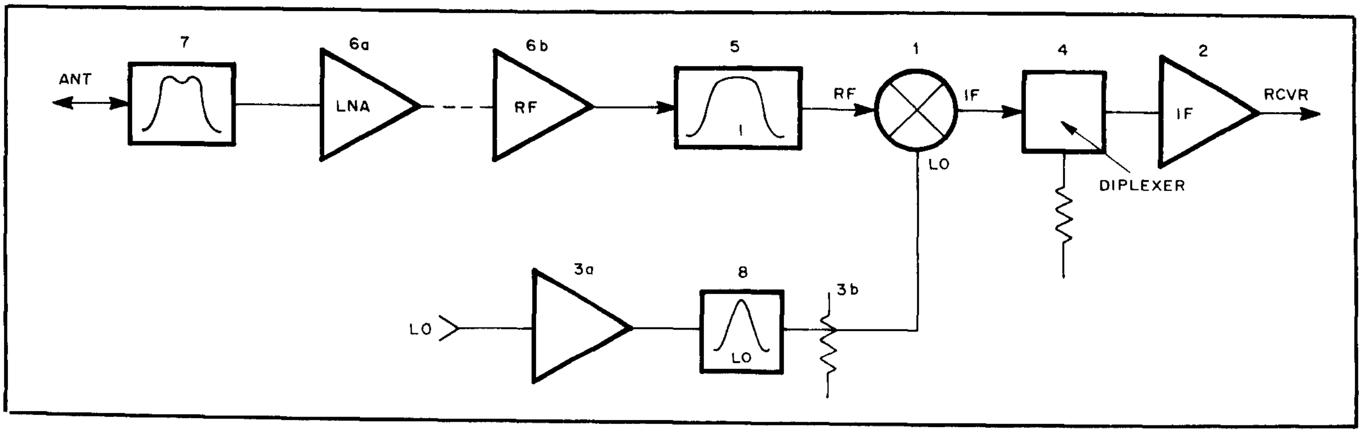


Fig 1

A Simple, Direct-Reading, Digital Inductance Meter

By Robert W. Vreeland, W6YBT
45 Waywood Dr
San Francisco, CA 94127

Have you ever designed a circuit that required a 0.12-μH coil and then wondered how you would measure the inductance after winding the coil? Only the most expensive inductance meters measure values less than 1 μH with reasonable accuracy. With the simple instrument described here, you can use a Fluke® 8060A (or similar multimeter) to measure inductance values from 0.05 μH to 400 μH.[1]

This inductance meter is basically an RF ohmmeter with built-in standard inductances of 1 μH and 10 μH. But, you say, an RF ohmmeter will measure impedance, not inductive reactance. The resistance of a small inductor changes only the phase angle of the impedance without significantly altering its magnitude (see Fig 1). The absolute value of the impedance is, for all practical purposes, equal to the inductive reactance. As shown in Fig 2, the same current, i, will flow through L1 and L2. Its magnitude and phase will be the same in L1 and L2. Also,

$$e1 = iZ1 = i(R1 + j2\pi fL1)$$

and

$$e2 = iZ2 = i(R2 + j2\pi fL2) \qquad \text{(Eq 1)}$$

Fig 1—For low-resistance RF coils, the magnitude of the inductive reactance, for practical purposes, is equal to the impedance.

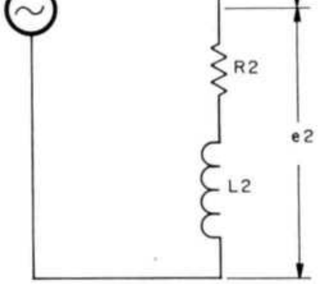


Fig 2—An RF ohmmeter can be used to find the ratio of two inductances.

The Fluke 8060A measures only the magnitude of e1 and e2 without regard for the phase angle. Therefore,

$$|Z1| = j2\pi fL1 \text{ and } |Z2| = j2\pi fL2 \qquad \text{(Eq 2)}$$

Now, let's take the ratio of e2 to e1:

$$\frac{e2}{e1} = \frac{i|Z2|}{i|Z1|} = \frac{i|j2\pi fL2|}{i|j2\pi fL1|} = \frac{L2}{L1} = \frac{L2}{10} \qquad \text{(Eq 3)}$$

if L1 is a 10-μH standard inductor. Notice that 2πf cancels out, so a stable signal source is not needed.

This inductance meter is easy to use: You simply adjust i so that e1 is exactly 100 mV. The voltage e2 will then be 100 mV when L2 is 10 μH, and 10 mV when L2 is 1 μH. When the 1-μH standard is switched in, 100 mV represents 1 μH, and 10 mV represents 0.1 μH. Each time the unknown inductance is changed, i must be reset.

Construction

I built my inductance meter in a 5 × 2½ × 1⅝-inch plastic box (GC Electronics 16-014). A 10-turn potentiometer, R1, is used to set the magnitude of the current, i.

Two Duracell® MN1604 alkaline batteries and an MC7808CT voltage regulator form the power supply. Battery drain is 185 mA on the high range, and 220 mA on the low range. Because this is a fairly high drain for transistor-radio

Notes

[1] Measurements made at low frequencies cannot be expected to correlate at VHF and above. If ferrite materials are used, measurement error may be minimized by accounting for the change in permeability, assuming the material characteristics are known.

batteries, two are used in series. This allows the batteries to be run down to about 5.5 V each before replacement is necessary. The batteries are good for several hours of use. Pin jacks are provided for checking battery condition. If you don't want to use batteries, you can use an ac-operated 12-V dc wall transformer or power supply.

Surprisingly, lead inductances are not a problem. The standard inductances are connected in the same way that you would connect a shunt for use with a dc meter. See Fig 3. The current source is connected between points A and B, with leads of any convenient length. The potential across the standard (or the unknown) inductor is measured between points C and D using leads of any convenient length. However, points C and D must be located at the points between which you want to measure the inductance. I use alligator clips and short leads for connecting the unknown inductor to points C and D.

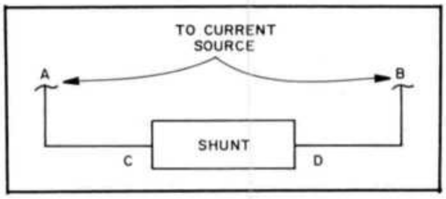


Fig 3—Measuring small inductances is like measuring 300 A of direct current using a standard 50-mV shunt. The location of the potential sensing points (C and D) is important.

Circuit Description

There is nothing unusual about the circuit (Fig 4). The 100-kHz oscillator uses a 2N3565 in a Colpitts circuit. The oscillator is emitter coupled to the 10-turn potentiometer, R1. This is followed by a Darlington pair of 2N5322s. Because an inductance of 0.05 µH has an impedance of only 0.0314 ohms at 100 kHz, an RMS output current of 160 mA is required to generate a 5-mV drop. It's easy to see the advantage of making measurements at 100 kHz instead of the more-commonly used 1 kHz, where 16 A would be needed!

A stud-mounted heat sink is used on the output transistor (Q3). The heat sink is secured to an aluminum bracket that also holds the batteries in place (see Fig 5). This bracket also serves as a heat sink for the MC7808CT regulator.

The RANGE toggle switch should have low contact resistance. I used an Alcoswitch MTA206N. The standard inductors should be mounted close to the RANGE switch as the switch is included as part of the inductance.

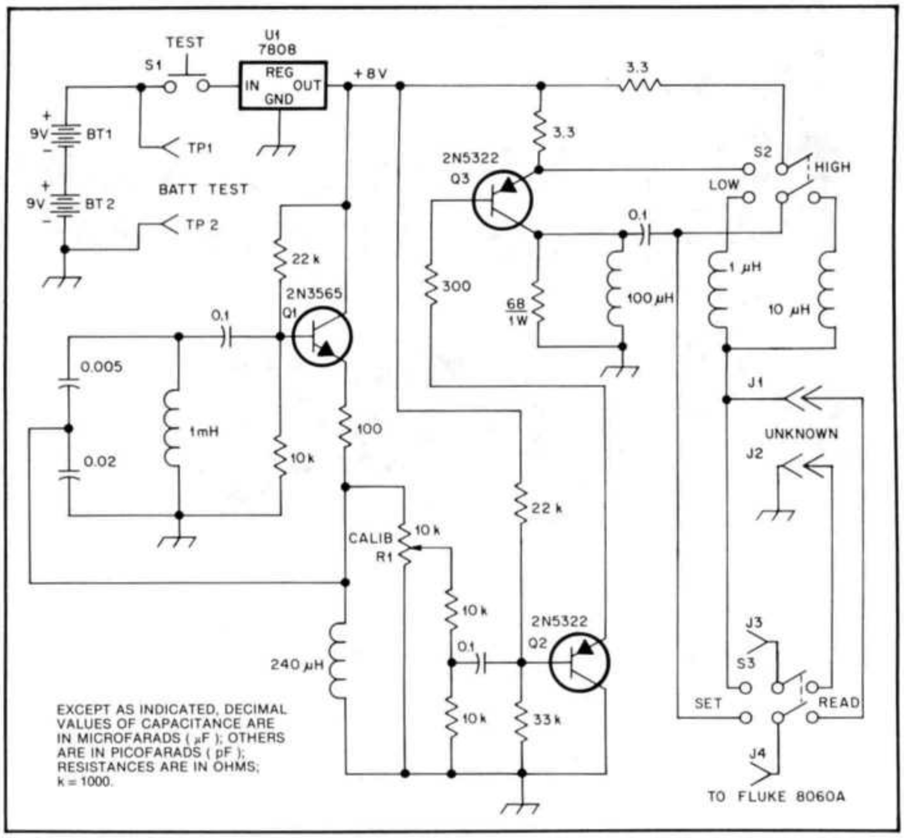


Fig 4—Schematic diagram of the inductance meter. This meter is designed for use with a Fluke 8060A multimeter.

The only special construction requirement is to keep the potential-sensing leads away from the high-potential end of the 100-µH output inductor. This inductor is available from Radio Shack® (273-102A). Any 100-µH choke capable of carrying 300 mA can be used.

The circuit was designed to perform with off-the-shelf components. Mylar® capacitors were used for low-leakage interstage coupling. A common disc-ceramic capacitor is used for non-inductive coupling to the coils under test. Carbon resistors were used throughout. The emitter-stabilizing resistors help reduce drift.

Because the Fluke 8060A is ac-coupled, thermoelectric potentials are not a problem. The '8060A reads RMS, making it unnecessary to provide a perfect sine-wave test signal.

There are only four controls (see the title photo). The TEST button is at the lower left (hidden by the activating index finger). Above the TEST button is the HIGH/LOW (range) switch; to its right is the SET-READ switch. The large knob controls the potentiometer (R1) to set the calibration at 100 mV.

Measurement accuracy depends on the accuracy of the 1- and 10-µH inductors used as standards. The 10-µH inductor is a common RF choke. The 1-µH inductor is wound with 17 turns of no. 20 enameled wire on a 2-W resistor. The turns are spaced to provide the desired inductance.

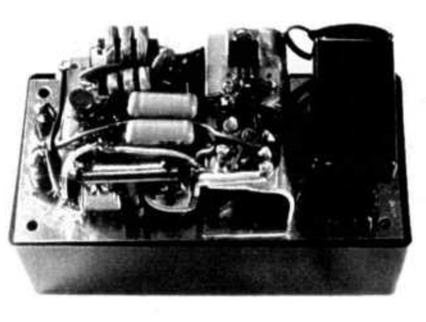


Fig 5—An aluminum bracket holds the batteries in place and provides a heat sink for the MC7808CT voltage regulator and the 2N5322 output transistor.

Testing the prototype required a bit of doing because I did not have access to a lab-grade inductance meter (such as the HP 4274A). First, I bought a half dozen 100-µH, 5-% tolerance RF chokes. I measured their inductance using an oscillator circuit and the time-honored (and time-consuming) resonant-frequency technique. The values had a ±3% spread, indicating that their average value was probably 100 μH. This, and a short piece of wire, became the standards for calibrating the resonant-frequency test oscillator. Once calibrated, the test oscillator was used to measure 15 test inductors. These, in turn, were used to test the instrument described here.

If you don't have temporary access to an inductance meter to select this instrument's standards, try this: Buy half a dozen 10-μH, 5-% RF chokes. Measure their inductance with this meter using any one of the chokes as the standard. The chances are good that the average measured value will be fairly close to 10 μH. Select the choke that measures closest to the average and use it as your 10-μH standard. Your inductance meter can then be used to measure the 1-μH standard.

Measurement accuracy of this instrument is shown in Table 1. The standard inductors were tailored for use with my '8060A. I have used the inductance meter with a borrowed '8060A and found that the accuracy of 15 out of the 20 measurements presented in Table 1 differed less than 5%; the other measurements were within 10%.

When measuring very small inductances, it is best to average two readings. The potential-sensing electrodes should be reversed for the second reading.

Table 1

Measurement Accuracy of the Inductance Meter

Test Inductance (μH)	*Percentage of Error*		*Fluke 8060A Scale*	
	Low Range	*High Range*	*Low Range*	*High Range*
0.0459	+3.5		200 mV	
0.0815	+4.0		200 mV	
0.169	+1.7		200 mV	
0.327	+4.6		200 mV	
0.561	+4.7		200 mV	
0.942	+3.2	-3.9	200 mV	200 mV
2.34	-2.4	-3.6	2 V	200 mV
6.12	+0.2	+4.2	2 V	200 mV
9.61	-1.6	+4.0	2 V	200 mV
23.18	-6.8	-3.0	20 V	2 V
48.2		-0.5		2 V
100.4		-1.2		2 V
203.3		-3.4		20 V
303.7		-2.6		20 V
403.7		-0.1		20 V

Receiver Front-End Protection

(continued from page 9)

istors, or MOVs as they are sometimes called, can also be used to clamp the transient. But because the MOVs conduct for the same voltage magnitude in both directions, there will be a reverse transient. For that reason, you will want to use a diode.

Some amateurs run dc power for the preamp up the *transmitter* feed line. This is not a good idea. Five hundred watts of output power develops 158 V across 50 ohms, possibly more if there's any SWR present. A good choke and feedthrough capacitor may provide enough attenuation, but such a procedure is risky. Low-power receive parts may fail, taking your preamp, too.

Feeding dc up the *receiver* feed line is a good way to help keep your transmit RF out of the power port. Chokes and bypasses should have an easy time of providing enough additional attenuation to provide long service. Obviously, received RF presents no problem.

The output of the preamp is quite sensitive to lightning. A lightning transient moving down the tower will be coupled to the feed line. Because the propagation constant of the tower and the feed-line jacket differ from that of the feed-line dielectric, the voltage between the center conductor of the feed line and the braid will differ. If you cannot protect the preamp transistor, goodbye transistor!

To dissipate the large amounts of energy that may be present, use a zinc-oxide Varistor or a Zener diode. A line of Zeners designed for this service is marketed under the name of Transzorb.® Both the Varistor and Zener diode have short response times and can dissipate large amount of energy. To obtain the fastest response time, mount the transient absorber as if it were a UHF part. Match the voltage rating of the Varistor or Transzorb to that of the power supply, if necessary. The price of Varistors is typically under $1 each from Allied Electronics.[1]

Transient absorbers should be placed as close as possible to the entry point of the enclosure to provide the greatest degree of protection. Transient absorbers should be placed at the output of the preamp power supply to protect it as well.

AC Power Line Protection

Varistors placed across the ac power lines entering the house will also lessen the transient seen by your equipment from a remote lightning strike. Transzorbs or any other type of Zener diode *should not be placed across an ac source.* When installing the Varistors, use caution! More people are killed by 240-V lines than other power sources.

Ground Systems

Ground systems for lightning protection are an area of controversy in the amateur community. Some people believe that the use of multiple ground rods increases your chance of being hit. If that's true, it's also true that multiple ground rods lower the ground resistance and decrease the voltage at the point it can enter the station. Ground radials also lower the ground resistance. Adding radials may be better than installing an extra ground rod. All ground rods—and the common point of the radials—should be tied together with low inductance, high-current capacity straps.

Notes

[1] Allied Electronics, 401 E 8th St, Fort Worth, TX 76102, tel 800-433-5700.

Bibliography

1. Alpha Semiconductor Catalog, Alpha Industries, Inc, Woburn, MA, 1985.
2. M. J. Howes and D. V. Morgan, *Reliability and Degradation: Semiconductor Devices and Circuits* (New York: John Wiley and Sons, Ltd, 1981).
3. R. Block, *The "Grounds" for Lightning and EMP Protection*, PolyPhaser Corp, 1425 Industrial Way, Gardnerville, Nevada 89410-1237, tel 702-782-2511.

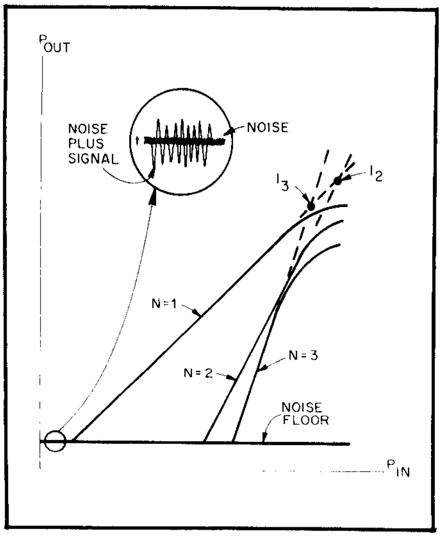


Fig 2

(continued from page 10)

input noise power. This is accomplished by multiplying the input noise by the receiver added noise measure, or noise factor. Thus, a perfect, noiseless receiver would have a noise factor F = 1.000 . . . (or a noise figure NF = 10 log F = 0 dB), indicating that only the input noise appears in the receiver output and no internally generated noise power is added. Similarly, a noise factor F = 2 (NF = 3 dB) shows that the receiver adds an amount of additional noise equal to the outside noise appearing at the input. Thus, the total noise power P_t = kTBF. Most modern amateur 1- to 10-GHz receivers can be made to have state-of-the-art noise factors/figures in this range, with total effective bandwidths (usually set by the narrowest filter in the receiver) of 250 Hz, so that receiver input power sensitivities down to about -144 dBm are possible! Total station sensitivity needs to add antenna gain (as a negative quantity) and loss of the antenna-receiver feed line, relays, etc.

Suppose that you start out with the simplest possible superheterodyne receiver: a mixer and a local oscillator, with a lower-frequency IF strip provided by a HF or VHF receiver. Up until 15 years ago, this *was* amateur microwave state-of-the-art and lots of effort went into making the mixer noise figure as low as possible, because this pretty much set the entire receiving system sensitivity. Why? Because the total noise factor F_{tot} of a series chain of N stages is:

$$F_{tot} = F1 + [(F2 - 1) \div G1] + [F3 - 1) \div (G1 \times G2)] + \ldots + [(F_n - 1) \div (G1 \times G2 \times \ldots \times G_n - 1)]$$

A bare mixer (component [1] in Fig 1) followed by even a low-noise IF receiver (and it *is* easier to get a lower noise figure at a lower IF frequency than at the higher microwave input frequency), has a high stage *loss* (gain G1 is less than one) and an even higher noise factor F1, so that the total noise figure NF is just about equal to the sum of the mixer noise figure NF1 and the IF receiver noise figure NF2. If NF2 is low (possibly by use of a very low NF amp [2], you can see that the mixer NF1 sets the noise performance of the whole receiver! Use of local-oscillator-chain components [3a/3b] to set the LO power to that level giving best NF was common; an IF diplexer [4] was often recommended as is an image-rejection band-pass filter [5] (for reasons discussed below), but these are lossy components which directly add their dBs of attenuation to the overall receiver noise figure and directly reduce sensitivity. On the other hand, if a stage or two [6a/6b] of relatively low-noise amplification precede the mixer, the mixer noise is now F3 and is reduced by the *product* of the gains of all previous stages; a very small mixer noise contribution is now present. My philosophy is: start with any working mixer, even if not great (just to get on the air), and add improvements (amplifiers, filters, etc) around the mixer to improve the receiver toward an ideal unit.

Notice in the graph of Fig 2, that the receiver is a linear subsystem over a limited range, and that output increases N = 1 times the increase in the input power over this range. There is a lesser increase above this range, indicating that the subsystem is saturating. Second (N = 2)-order, third (N = 3)-order and higher-order distortion products occur, but this is not a present problem in amateur state-of-the-art receivers and will not be considered.

Selectivity is the receiver's ability to distinguish desired frequencies from the surrounding undesired frequencies (the frequency domain analog property of the amplitude domain sensitivity property). For example, in the frequency plot of Fig 3, if the desired signal, at $F_d = F_{LO} + F_{IF}$, is of small amplitude (close to the noise level), then to allow the noise at the image frequency, $F1 = F_{LO} - F_{IF}$, into the mixer is to reduce sensitivity by up to 3 dB! The image noise is removed by use of the frequency-selective, or rejective, properties of BPF [5] of Fig 1; either the wider filter BPF1 or the narrower filter BPF2 will be fine, as the response at F_i is down 90+ dB. Why use a narrower filter? Look at the envelope of the LO signal, at F_{LO}; these noise sidebands are present on all man-made signals, but are generally undesirable. While wider BPF2 reduces the noise sidebands by about 80 dB, the narrower BPF1 reduces then even more; whether the extra insertion loss through a narrower BPF is worth the extra LO noise-sideband attenuation is a factor that has to be determined in each particular case.

It is also beneficial to prevent other undesired signals from reaching the mixer [1]; the larger the amplitude of the undesired signal, the more beneficial removal of that signal is. A larger amplitude signal (say, the n_{th} harmonic of a lower-band transmitter, as a carrier at frequency N_xF_t, along with its noise sidebands) can overwhelm a receiver and mask a desired weaker signal (at F_d) by one of several processes. The easiest solution is a BPF [7] right at the receiver input, to attenuate the undesired off-frequency signal as soon as possible in the receiver chain. Here, the use of a filter with as low an insertion loss (IL) as possible, is mandatory as the IL precedes the gains of amplifier stages 6a/6b and thus directly adds to the receiver noise figure. Similarly, a filter [8] may be needed in the LO chain, to prevent F_{LO} harmonics or spurious signals from entering the mixer; the LO filter should be after any active/nonlinear stages in the LO chain (since it is these stages which produce the undesired signals).

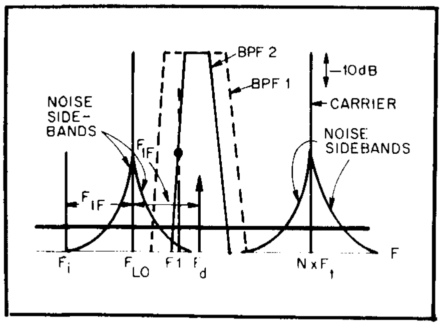


Fig 3

Stability of the receiver is the ability of the local oscillator to stay at its desired frequency $F_o = F_d - F_{IF}$. If the LO shifts frequency by more than the bandwidth of the narrowest filter in the receiver, the desired signal moves out of the passband and can not be heard. For example, if the LO signal frequency decreases, the signal in the IF and become the undesired signal at frequency F1, rather than the desired signal at F_d. Note that the F1 signal is attenuated 50 dB by the narrower BPF2, but not by the wider BPF1. A local oscillator with less-than-adequate stability just adds one more factor (signal frequency) to change, as by requiring IF tuning, when attempting weak-signal work.

Spuriousity is the generation of undesired signals by any stage of the receiver. A typical spurious signal might be due to oscillation in an amplifier stage (this is another form of stability problem, but is given a different name for distinguishment). Of all the problems in a receiver, this is both the easiest to find by testing and to then remedy on paper, but often the hardest to remove in actual practice.