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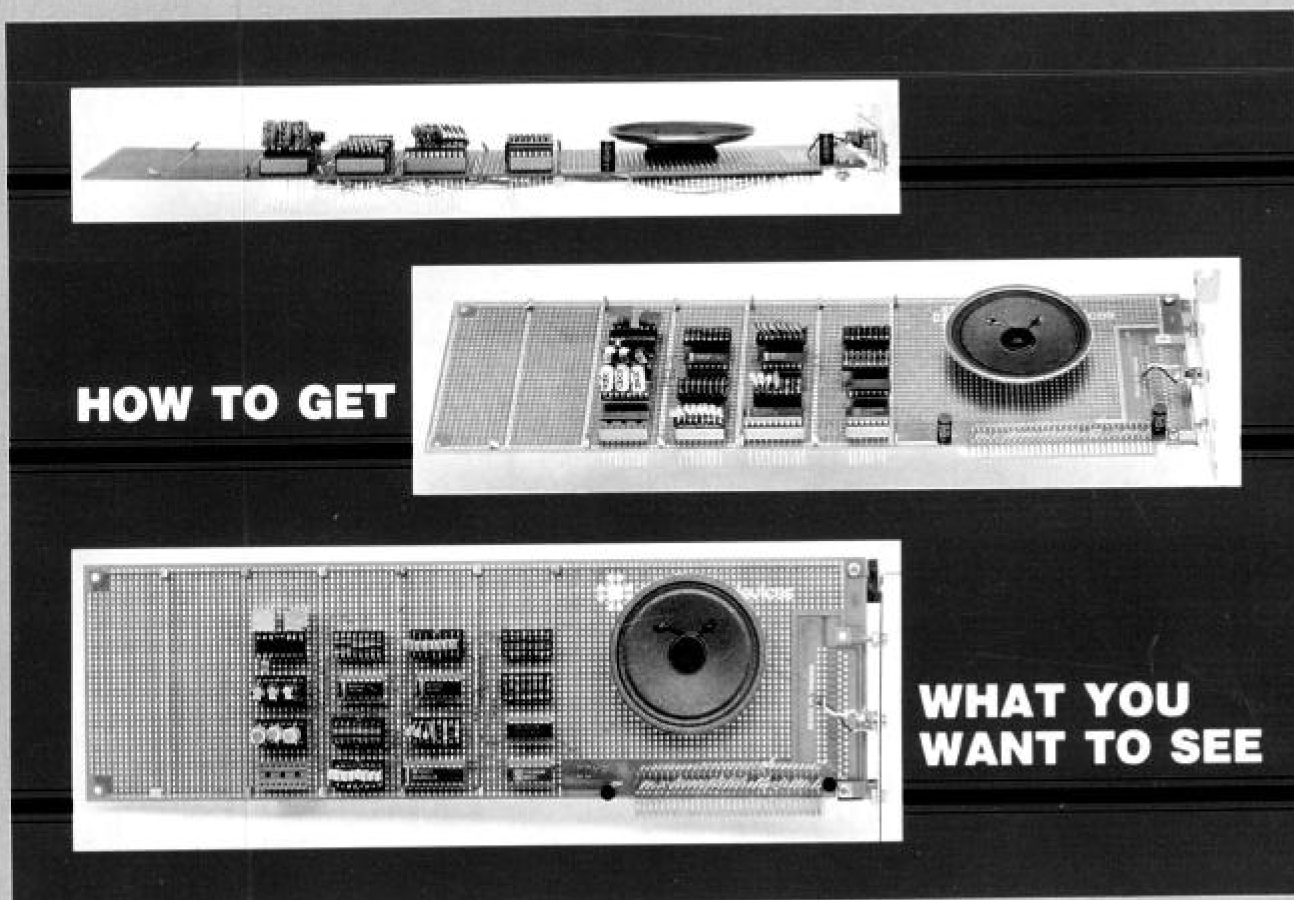

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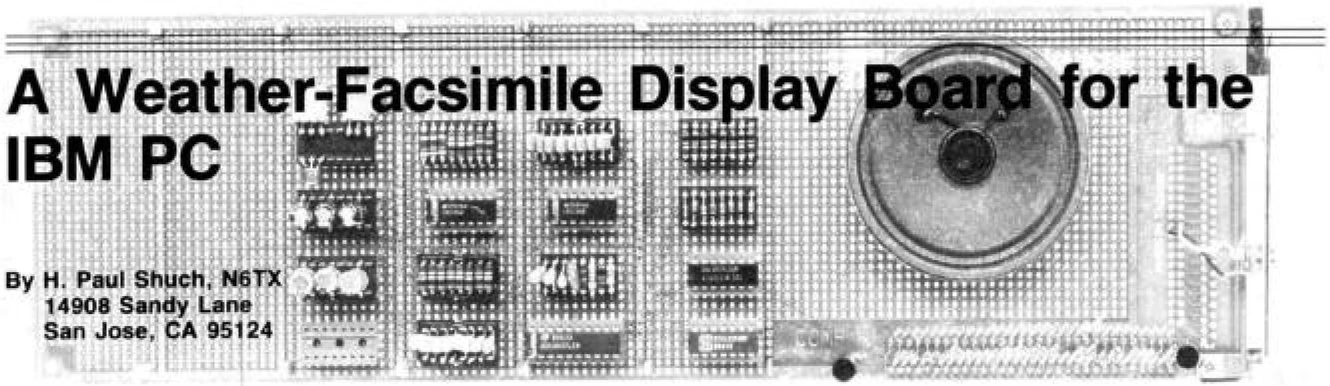
Here's a project that should whet the appetites of the growing number of WEFAXers. No more boxes to clutter your operating desk; this interface hides in your PC!

A Weather-Facsimile Display Board for the IBM PC



By H. Paul Shuch, N6TX
14908 Sandy Lane
San Jose, CA 95124

About fifteen years ago, when I first became involved in the fascinating process of receiving pictures of the Earth from weather satellites,[1] several image-display options existed. Like most experimenters, I tried them all. Although electrostatic printers, rotating-drum facsimile machines, slow-scan TV monitors, storage oscilloscopes, and Polaroid time exposures from CRT displays all produced usable and exciting pictures, I longed for an easier way. I wanted a display with no moving mechanical parts, no messy chemicals, no fumes from sparking Teledeltos paper, and no chance variations in contrast and density from one picture to the next. I reasoned (as did many other radio amateurs at the time) that the ultimate display would involve digitizing an image and storing it in computer memory for manipulation, enhancement, and ultimate display on a video screen.

Unfortunately, technical and financial realities put such a display totally out of reach for the growing community of WEFAX experimenters. Well before the personal-computer revolution, the few of us who had access to our own computers were limited by the memory they contained. Sixteen or 32 kbytes of memory was considered all one would *ever* need for even the most demanding applications(!). Magnetic-core memory was the rage then, and at about one cent per "donut," the half-megabyte or so necessary to store one frame of satellite imagery cost about $40,000! If that wasn't enough to discourage an experimenter, the size and slothfulness of the pre-microprocessor computer usually was!

Computer Evolution

Although the 6502, 8080 and Z80® -based computers of the late '70s were manageable in terms of size and speed, and solid-state memory was fast becoming affordable, these 8-bit machines could directly address only 64 kbytes of memory. A few experimenters managed to digitize small portions of a WEFAX frame, for limited-resolution display. But computer display of the full frame of satellite imagery—in all its glory—still eluded us . . . until recently.

I've never been a great fan of the MS-DOS® operating system. Still, the IBM® PC (and its imitators), with its 16-bit internal architecture and ability to address 640 kbytes of memory, finally made WEFAX digital display practical. And, with bipolar RAM below $100 per Mbyte, the ubiquitous PC clone has fast become the computer of choice for weather-satellite enthusiasts.

Software

Now, what about software? Elmer Schwittek, K2LAF, made a significant contribution with his programs REAL-TIME.BAS and MAGNIFY.BAS,[2] WXFAX.BAS,[3] MULTIFAX.EXE, and the most recent versions of Multifax,® MF2.1 and MF3.0.[4] Which version of the program you should use depends on the equipment at hand. If you have a color-graphics adapter (CGA), use MF2.1. MF3.0 can be used *only* with an enhanced-graphics adapter (EGA). You *can't* use a monochrome display adapter (MDA) or Hercules graphics adapter (HGA); they are *not* compatible with the Multifax programs!

I designed the latest version of the FaxBoard—an all-inclusive interface between the audio output of a WEFAX receiver and the I/O bus of the IBM PC—around Elmer's MF3.0 software. However, the FaxBoard is compatible with *all* versions of the software. The FaxBoard is not available as a commercial product; you'll have to build your own. But then, that's what Amateur Radio is all about!

Interface Hardware Requirements

A weather-satellite receiver produces as its output an audio tone (typically 2.4 kHz), the amplitude of which varies as a function of video intensity (brightness). To display the image on a computer's video monitor, it is necessary to both demodulate the instantaneous amplitude of the audio subcarrier, and to periodically digitize that amplitude for storage and display. The FaxBoard performs these two functions, and a few others, as shown in the block diagram of Fig 1. The schematic diagram of the board is shown in Figs 2-4; a parts list appears in Table 1.

Audio output from the receiver is first applied to a high-pass filter (U1A) to strip off any hum and low-frequency noise that might be present. An audio AGC stage (U1B and associated components) maintains a constant video level, but in the process may generate distortion products, which are removed in an active bandpass filter (U1C). Contrast amplifier U1D establishes the appropriate drive level to U2A and U2B, a full-wave audio-subcarrier demodulator. The signal is next filtered in an active low-pass filter (U1C), to remove any vestiges of the original subcarrier from the video waveform that is sampled and displayed. Buffer U2D represents the final analog gain stage, establishing the appropriate drive level for the analog-to-digital (A/D) converter.

Digitization is accomplished in U3, an internally clocked CMOS A/D converter, the Tri-State® parallel outputs of which are enabled by the address decoder circuitry (to be described), providing an 8-bit digital word. Note that MF2.1 supports only the *two most significant bits* of this signal, thus can display an image in up to four colors (or video levels). MF3.0, the EGA version of K2LAF's program, supports two, three or four bits, for significantly more shades/colors. Future software products may permit the use of even more bits per pixel. Currently, FaxBoard 3 provides an 8-bit (256-level) capability, in anticipation of future software enhancements. Low-resolution-display software uses fewer of these bits.

[1]Notes appear on page 15.

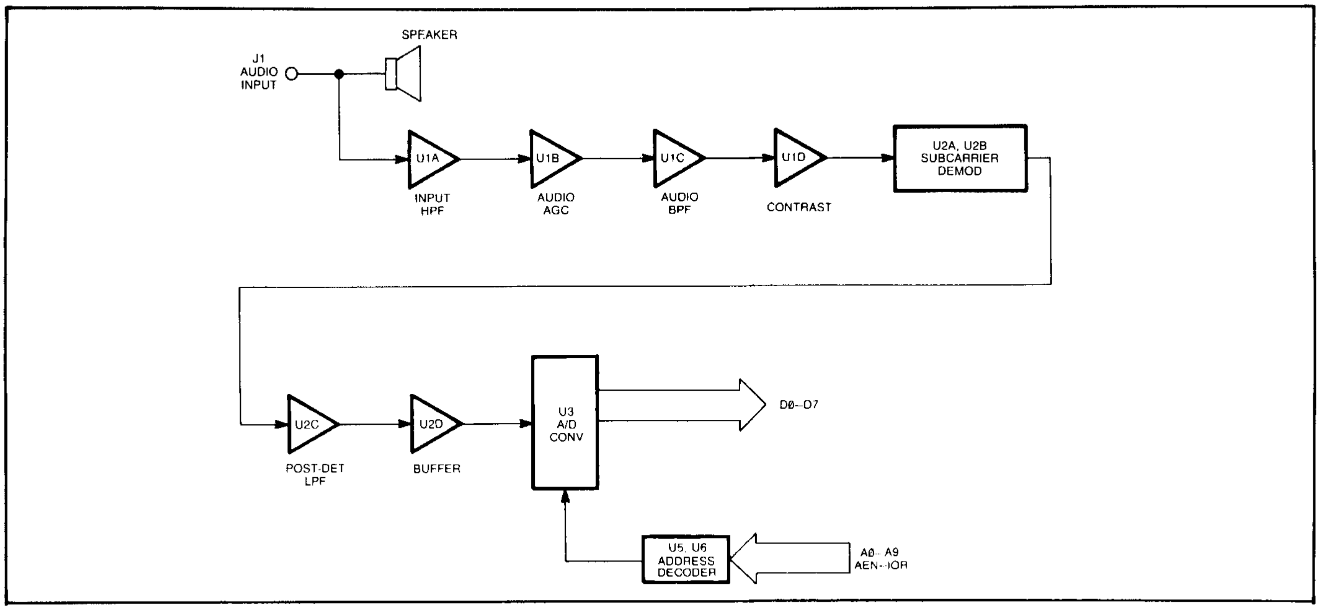


Fig 1—A block diagram of the FaxBoard.

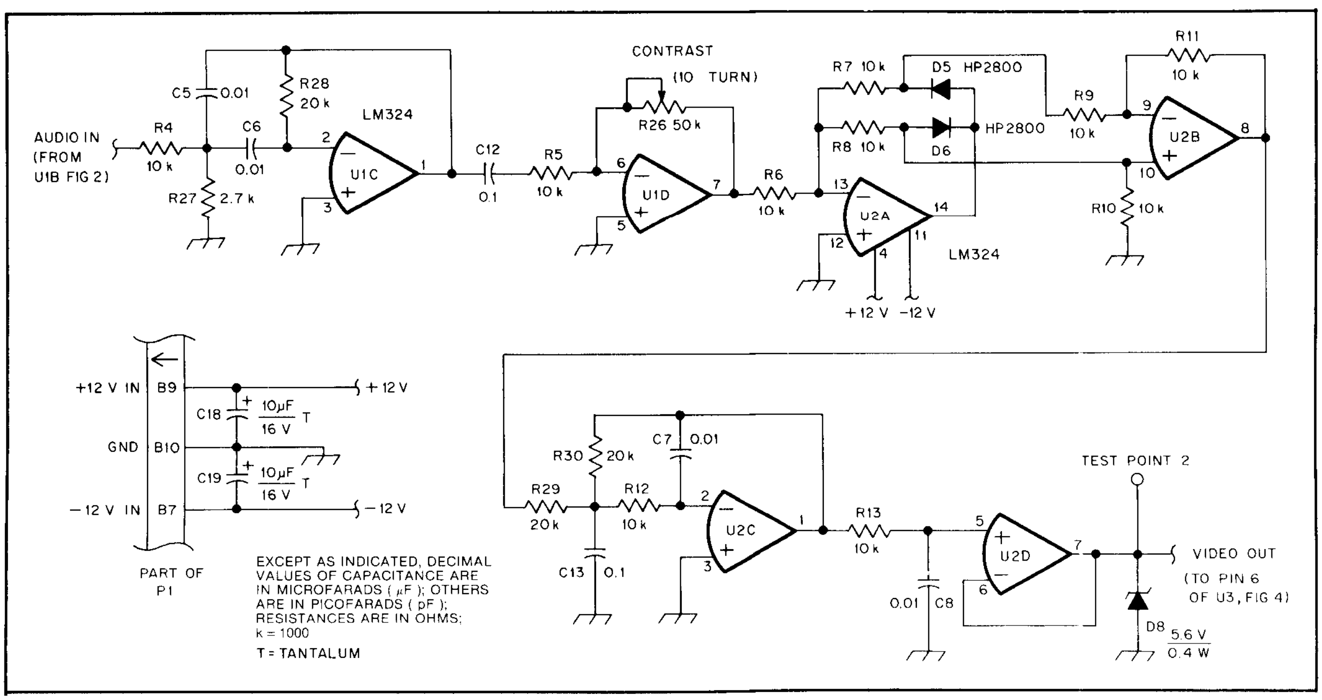


Fig 3—Active audio-bandpass filter (U1C), contrast amplifier (U1D), full-wave audio-subcarrier demodulator (U2A and U2B) and active audio low-pass filter (U1C) stages of the FaxBoard. U2D, the final analog gain stage and buffer, establishes the appropriate drive level to the A/D converter of Fig 4. With no input signal applied, and having properly adjusted the AGC CALIB control (see Fig 2), adjust the CONTRAST control for a 5-V P-P reading at test point 2.

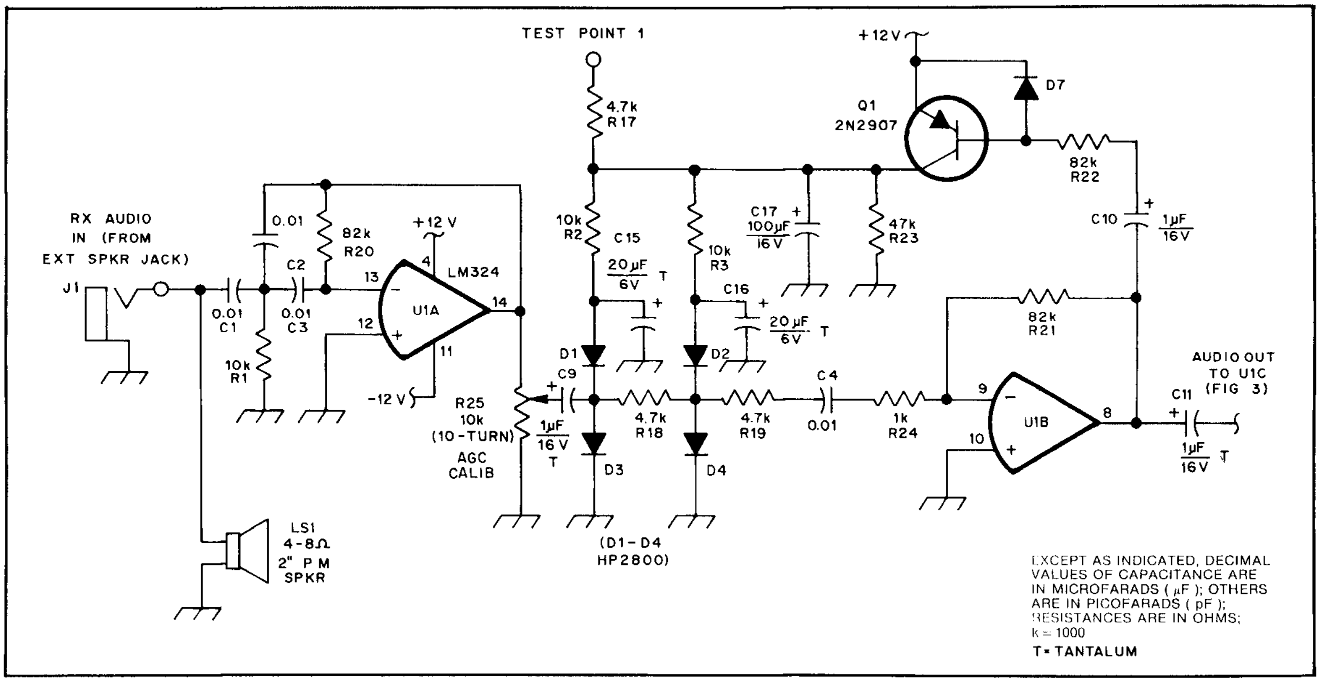


Fig 2—Input, high-pass filter and AGC stages of the FaxBoard. With no input signal applied, adjust the AGC CALIB potentiometer for a 50 µA reading with a microammeter attached to test point 1.

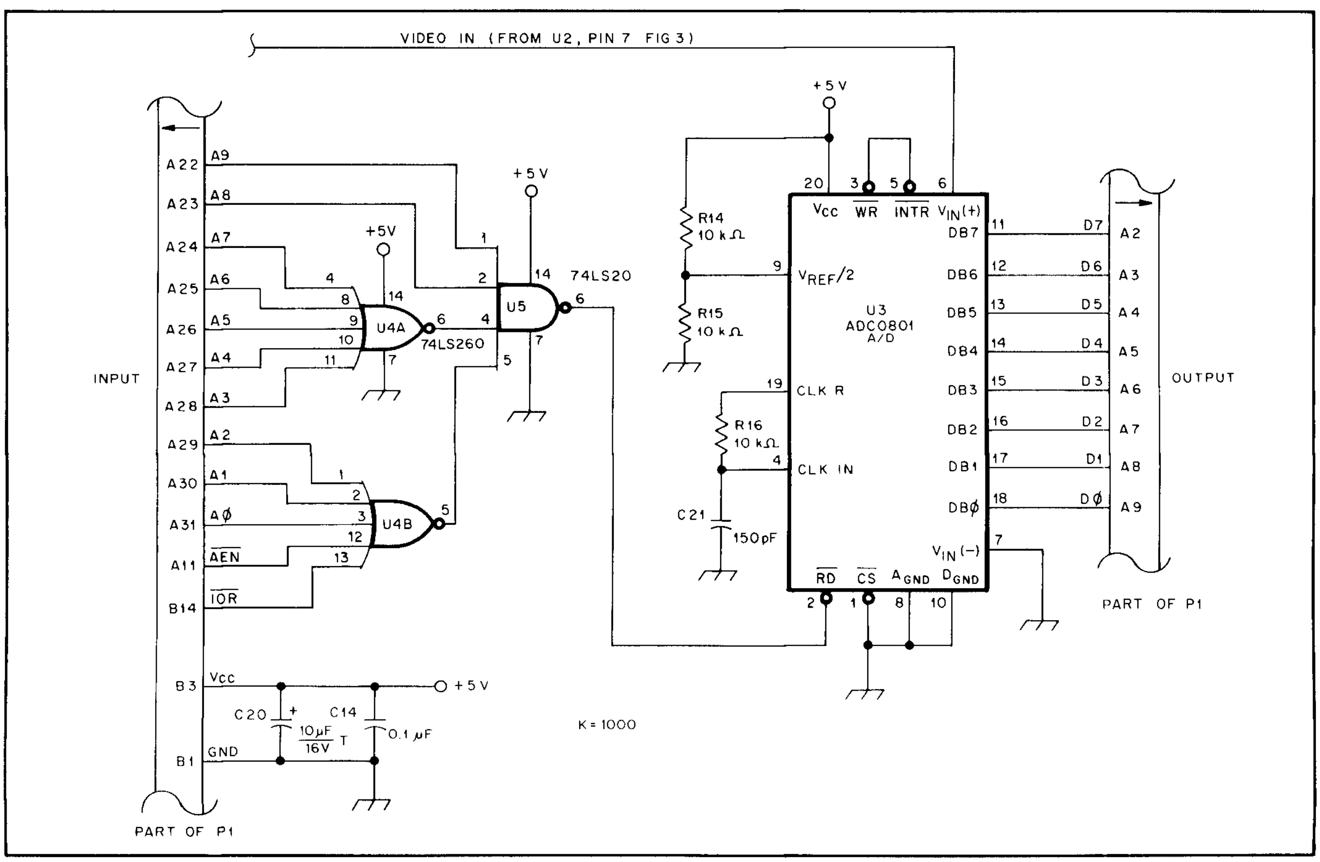


Fig 4—The A/D stage of the FaxBoard. The pin identifiers for P1 of the prototyping board are labeled within the block. The A identifiers refer to pins on the component side of the board; B identifiers refer to the wire-wrap side of the board (see text).

Table 1

Parts List

Unless otherwise specified, all resistors are ¼-W, 5% tolerance carbon-composition units; disc ceramic capacitors are 25-V units.

Part Identifier	*Mount to Header #*	*Part Identifier*	*Mount to Header #*
C1-C8—0.01-μF disc ceramic	1	R17-R19—4.7 kΩ.	9
C9-C11—1-μF/16-V tantalum.	2	R20-R22—82 kΩ.	9
C12-C14—0.1-μF disc ceramic.	2	R23—47 kΩ.	10
C15, C16—20-μF/6-V tantalum.	3	R24—1 kΩ.	10
C17—100 - μF/16-V tantalum.	3	R25, R26—10 kΩ, ⅛-W ten-turn trimmer potentiometer	6
C18-C20—10-μF/16-V tantalum.	4		
C21—150-pF silver mica.	2	R27—2.7 kΩ.	10
D1-D6—HP5082-2800 or equiv (see text).	5	R28-R30—20 kΩ.	10
D7—1N914 silicon diode.	5	SP1—4-8 Ω, 2-in. diam speaker.	
D8—1N752 (5.6-V/400-mW) Zener diode.	5	U1, U2—LM324 quad op amp.	
J1—⅛-in. phone jack.		U3—ADC0801 A/D converter.	
Q1—2N2907 or equiv.		U4—74LS260 dual, low-power Schottky, 5-input NOR gate.	
R1-R16—10 kΩ.	7, 8	U5—74LS20 dual, low-power, Schottky 4-input NAND gate.	

Misc.

JDR wire-wrap prototyping card (JDR-PR1); JDR Microdevices, 110 Knowles Dr, Los Gatos, CA 95030, tel 800-538-5000.
Four 14-pin DIP wire-wrap sockets.
Ten 16-pin DIP wire-wrap sockets.
One 20-pin DIP wire-wrap socket.
Ten 16-pin DIP headers.

Once the digital intensity information is generated, the controlling software needs to sample it periodically for input to memory via the computer's I/O channel. This is done through memory mapping, enabled by an I/O read command, and inhibited during direct-memory-access (DMA) operations with the address-enable signal, as decoded by gates U4 and U5. Please note that the I/O address selected for the FaxBoard is &h300, (the "&h" representing hexadecimal notation) the first address assigned by IBM to their prototyping card. The default address for image input assumed by the Multifax program is &h201, the first game-port address. This address, if used, would create a conflict between the FaxBoard and any device connected to the joy-stick port. Fortunately, in its SETUP option, the Multifax program allows you to specify the I/O address desired. FaxBoard circuit users should remember to set up their software for I/O address &h300.

Receipt of valid address, enable and I/O read commands activates the Tri-State buffers within U3, momentarily transferring the A/D converter output to the computer data bus. From there, each picture element can be stored on disk, or displayed on screen, under software control.

Circuit Credits

The analog and digital circuitry both borrow heavily (and shamelessly) from the works of others.[5-10] I claim no originality here, having merely adapted widely used circuits to a single PC prototyping card.

The material referred to in note 5, the definitive study of digital scan conversion, is a historically significant document. It was published prior to the proliferation of personal computers, and represents the first known attempt to integrate analog signal processing, A/D conversion, and solid-state digital memory into a single package. I highly recommend to all WEFAX experimenters the *Weather Satellite Handbook,* (see note 6) written by Ralph Taggart (WB8DQT). The book is an excellent overview of weather-satellite systems, receive hardware options, and competing display technologies. The digital circuitry design was guided and inspired by the information contained in *Handbook of Software and Hardware Interfacing for IBM PCs,*[11] which I recommend to anyone wanting to understand more about the architecture of the IBM PC bus.

The *Journal of the Environmental Satellite Amateur Users' Group*[12] is a quarterly to which most weather-satellite enthusiasts should subscribe. It periodically carries useful technical articles, which enable WEFAX experimenters to share ideas and accomplishments. At least one computer bulletin board[13] similarly caters to the WEFAX enthusiast.

Fabrication Considerations

One major objective of the FaxBoard project was the integration of all interface circuitry onto a single circuit board, so everything required for WEFAX reception, with the exception of the RF hardware, could disappear into the computer. This was done by constructing all of the circuitry on a single prototyping card,[14] using wire-wrap techniques. Wire-Wrap DIP sockets are installed on the card not only for the ICs, but also for all of the discrete components. The discrete components are mounted on DIP headers that plug into the sockets; this eases the wire-wrapping of all interconnections.

Fig 5 shows how I positioned the various ICs and headers (labeled with H numbers) on my prototyping card. This is merely an example; layout is not critical, nor are lead lengths, with the exception of power-supply-decoupling capacitors. These capacitor's leads should be routed to provide the shortest possible path to ground. Similarly, the power-supply leads for each IC *should not be daisy-chained,* but connected directly to the etched power bus on the board, using a separate wire for each device.

Remember that all input and output signals to the PC bus—as well as all four computer power-supply voltages (+12, −12, +5 and −5)—appear on the 62-pin edge connector (P1) of the prototyping card. Edge-connector pin numbers are shown in the schematic of Fig 4. The A identifiers represent the component side, the B side being the wire-wrap side of the circuit board. Pin numbering starts with 1 at the connector pin nearest the board's mounting bracket. The card I used (and recommend) is silk-screened on both sides with signal names printed near each pin of the edge connector. Check the pin identifiers against those called out in the diagram while you're wiring the FaxBoard. Connections to the individual edge-connector-pin holes are made by means of

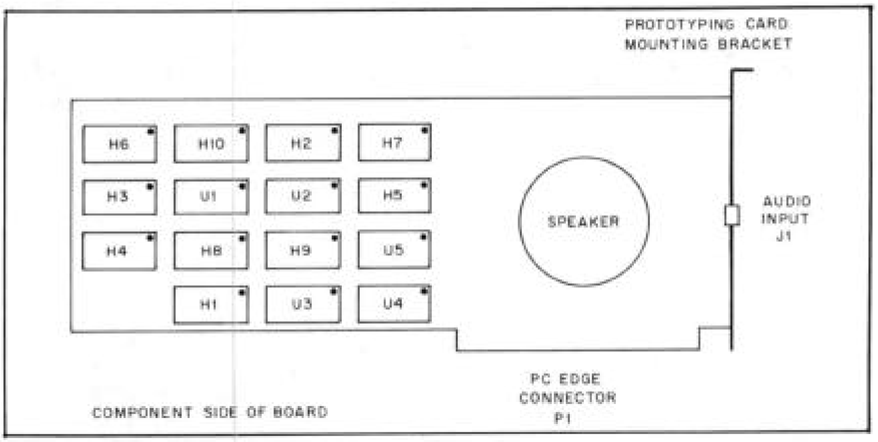


Fig 5—Positions of the ICs and headers (labeled with H numbers) on the prototype FaxBoard.

rows of 0.1-inch-spaced wire-wrap pins.

All components used in the FaxBoard design are common, and should be available from most surplus or mail-order houses. Don't overlook your local Radio Shack® store as a parts source. The digital ICs I used are all low-power Schottky (74LS) devices, although the 7400-series TTL ICs will work just as well. The HP diode types indicated for use in the AGC limiter and subcarrier demodulator circuits are not critical; any reasonably fast hot-carrier diode will suffice. All resistors are ¼-W, 5% carbon composition or metal film; all capacitors should be rated for at least 20 V, unless otherwise specified on the schematic.

Tune-Up and Test

If desired, the digital circuitry (Fig 4) can be built first, and tested with the Multifax software by connecting the VIDEO INPUT (U3, pin 6) to the wiper of a 10-kΩ potentiometer, which is connected between +5 V and ground. Select Option 1 (SET PICTURE memory limits and data port) from the Multifax Main Menu, and enter I/O address &h300 into the program's default file. (Note: The menu options I refer to here are for MF2.1. The MF3.0 menus are slightly different, but are explained in the software manual.) Next, select Main Menu option 2 (RECORD a new PICTURE into memory), and vary the potentiometer to simulate incoming video data. You should see color bars forming on the screen.

Once correct operation of the digital circuitry is verified, the analog circuits should be built and tested. Audio to the FaxBoard comes from the external speaker jack of your VHF or microwave weather-satellite receiver. Because plugging an external speaker into this jack generally disables the internal speaker, I included a small 4-Ω speaker on my board. Being able to hear the signals greatly simplifies antenna aiming and receiver tuning.

With a WEFAX transmission tuned in, adjust your receiver volume for a comfortable listening level using the FaxBoard's speaker. Connect a microammeter to test point 1, and adjust the AGC CALIB trimmer potentiometer for an indication of 50 μA with a clean signal present. Next, hook an oscilloscope to test point 2 (use of a 10:1 probe is recommended) and observe the demodulated video waveform. Adjust the CONTRAST trimmer potentiometer for a 5-V peak-to-peak signal at test point 2.

With the calibration potentiometers set, level optimization is performed with the WEFAX receiver's volume control during the phasing interval at the beginning of an actual picture transmission. Run the Multifax program, and from the Main Menu, select Option 2 (RECORD a new PICTURE in Memory). During the phasing interval, you will need to adjust the receiver volume control for the lowest level that produces white (or whatever color you have assigned to maximum video intensity) on screen. Decrease the receiver volume until the color changes, then increase the volume just to the point at which the desired color is again visible on screen. This verifies that the video amplitude is within the range of the A/D converter, and completes alignment of the FaxBoard.

It's still necessary to optimize the timing loop of the Multifax software to synchronize with your computer's clock rate. Instructions for this process are included in the Multifax manual. Following the procedures outlined, you should soon be observing digitized WEFAX images, in false color, almost in real time. Fig 6 shows a dot-matrix printout of such an

(continued on page 15.)

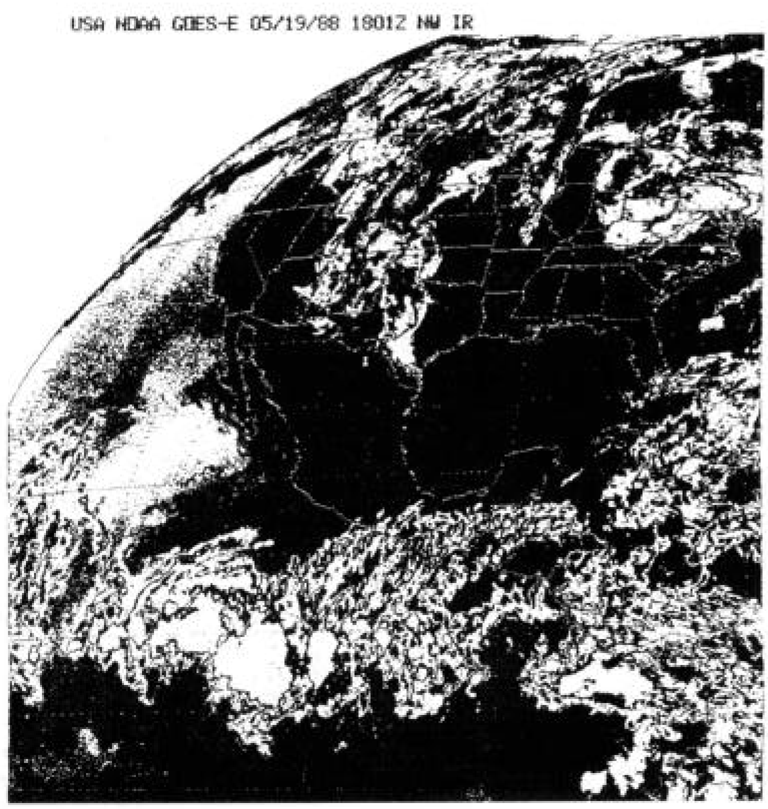


Fig 6—A dot-matrix printout of a WEFAX image, captured using the K2LAF Multifax program. On screen—and in color—your pictures will look even better. ***(Picture courtesy of Elmer Schwittek, K2LAF.)***

dish reflector antenna is:

$$G = 7.5 + 20 (\log f + \log D) \quad \text{(Eq 1)}$$

where
G = gain in dB
f = frequency in GHz
D = diameter in feet

This equation assumes feed efficiency and illumination factors of about 0.5, which is practical for most home-built units. Thus, a 20-foot-diameter dish, if built with a mesh surface having a sufficiently close weave, will have a gain of about 26 dB. The same dish (with the appropriate feed systems) should give gains of about 33 dB at 902 MHz and 36 dB at 1296 MHz, if the screen mesh is fine enough.

Energy must be directed to and from the *focus* or *focal point* of a dish to realize the maximum gain of the dish (see Fig 1). There are a number of methods of placing feed elements for more than one band at the focus of a dish. The focal length (f) of a dish is related to the dish diameter (D) and physical center depth (C) by

$$f = D^2/16C \quad \text{(Eq 2)}$$

The equation governing the parabolic shape is

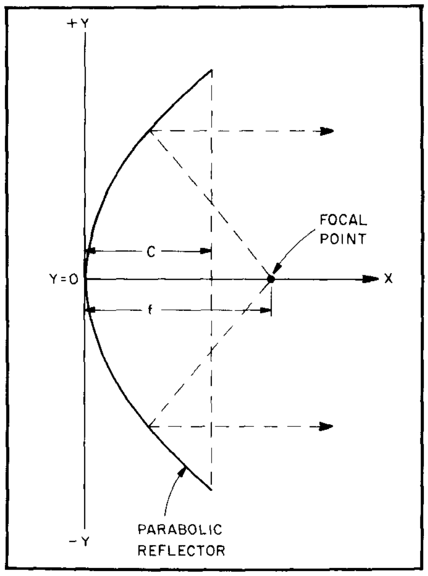


Fig 1—Cross section of the center of a parabolic dish, showing the physical center depth (C), focal length, and location of the focus (f). A dish feed must be placed at f for optimum antenna performance, which makes multiband use of a single dish challenging.

$$y^2 = 4fX \quad \text{(Eq 3)}$$

In designing a parabolic dish, Eq 3 is more useful in the form

$$y^2 = 4D\,(f/D)X \quad \text{(Eq 4)}$$

Eq 4 emphasizes that the focal-length-to-diameter ratio f/D, generally set by the illumination factor of the dish feed, is the most important consideration in dish design. Typical dish feeds work best with f/D ratios between about 0.3 and 0.5. For our 20-foot-diameter dish example, this gives focal lengths of 6 to 10 feet, and center depths of 4 feet 2 in. to 2 feet 6 in., respectively. Details on building dishes can be found in many VHF/UHF manuals. Next month, I'll continue the discussion of the state-of-the-art 432-MHz station.

Notes
[1]For information, write Harold W. ("Rusty") Landes, Jr, KA0HPK, PO Box 126, St Mary of the Woods, IN 47876.
[2]S. Powlishen, "An Optimum Design for 432-MHz Yagis," *QST*, Dec 1987, pp 20-24, and *QST*, Jan 1988, pp 24-30.

A Weather-Facsimile Display Board for the IBM PC

Continued from page 7.

image, using circuitry similar to that described here, and the K2LAF Multifax program. On screen—and in color—your pictures should look even better. Enjoy your FaxBoard!

Notes
[1]H. P. Shuch, "A Cost-Effective Modular Downconverter for S-Band WEFAX Reception," IEEE Transactions on Microwave Theory and Techniques, Dec 1977, p 1127.
[2]E. Schwittek, "WEFAX Pictures on Your IBM PC," *QST*, Jun 1985, pp 14-18.
[3]E. Schwittek, "HF WEFAX on the IBM PC," *QST*, Dec 1986, pp 46-47.
[4]Multifax 2.1 and 3.0 are available from Elmer Schwittek, K2LAF, 2347 Coach House Lane, Naples, FL 33942; price $49 each.
[5]C. Vermillion, and J. Kamowski, "Weather Satellite Picture Receiving Stations, APT Digital Scan Converter" *NASA Technical Note D-7994*, NASA Goddard Space Flight Center, Greenbelt, MD, May 1975.
[6]The third edition of the *Weather Satellite Handbook* is available from R. Taggart, 602 S Jefferson, Mason, MI 48854; price $12.50, postpaid in the US.
[7]G. Zehr, "The VIP: A VIC Image Processor," *QST*, Aug 1985, pp 25-31.
[8]R. Cawthon, "Attention, Weather Watchers!", *73 Magazine*, Oct 1978, pp 218-223.
[9]K. Sueker, "Real-Time HF WEFAX Maps on a Dot-Matrix Printer," *QST*, Mar 1986, pp 15-20; Feedback, *QST*, Jul 1986, p 43.
[10]M. Goodman, "Weather . . . Or Not?", The Rainbow, Feb 1985, p 42.
[11]J. Royer, *Handbook of Software and Hardware Interfacing for IBM PCs* (Englewood Cliffs: Prentice-Hall, 1987).
[12]The *Journal of the Environmental Satellite Amateur Users' Group* is edited by G. Mengell, 2685 Ellenbrook, Rancho Cordova, CA 95670. Subscription rate is $12/yr.
[13]DataLink RBBS, Dr Jeff Wallach (N5ITU), sysop, tel 214-394-7438.
[14]The IBM-PR1 wire-wrap prototype card is available from JDR Microdevices, 110 Knowles Drive, Los Gatos, CA 95030, tel 800-538-5000; price $27.95 plus shipping.