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ADD WAVEFORM STORAGE TO YOUR OSCILLOSCOPE

Converts any scope with external trigger input into a digital storage unit

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HAVE you ever wished you owned a storage oscilloscope to see those transient waveforms and random events that escape you? Now you can savor these signals without spending thousands of dollars. Moreover, you can enjoy the advantages of digital storage as compared to analog (CRT) storage, all for about $228.

Called the "Wavesaver," this black box can convert virtually any conventional oscilloscope that has an external trigger input into a digital storage scope. Its 1K x 8 memory stores random or repetitive analog waveforms with a vertical resolution of 256 discrete steps (8 bits), sampling to a 500-kHz rate. It features pretriggering to capture signals before the trigger occurs, as well as post-trigger viewing. In conjunction with an ordinary oscilloscope, you can view signals as they occur or save them for later examination. Furthermore, the Wavesaver can save waveforms to obtain hard copy when used in its plot mode since interfacing is built in for use with a chart recorder.

How It Works. The Wavesaver combines A/D (analog-to-digital) and D/A (digital-to-analog) converters with RAM (random access memory) to significantly enhance a conventional single-trace oscilloscope. It also has digital storage features that provide "sampling" and "quantizing." Sampling involves obtaining voltage levels representing an analog input signal at discrete points in time and quantizing is the transformation of these values into binary numbers by an A/D converter. You determine how often this process occurs by using a very precise digital clock. Once the data is in the digital memory, it can be read out at a fixed rate and reconstructed for displaying. (See box.)

In the Wavesaver, sampling and quantizing are performed so that every voltage sample derived from a series of very narrow contiguous time slots is converted to a binary number using an A/D converter. The binary data is then stored in a 1024 by 8-bit RAM with each time-slot's value stored as one 8-bit byte. The process continues until all 1024 bytes in the RAM are filled. The digital data can then be read out of the memory and passed through a D/A converter, which reconstructs the original analog waveform for application to the conventional single-trace oscilloscope. Since the RAM can be nondestructively read out indefinitely, the reconstructed display will remain on the CRT screen as long as the user desires.

Besides the previously mentioned A/D, D/A, and RAM features, the Wavesaver, shown in block diagram form in Fig. 1, also has provisions for driving an external plotter or other digital system.

Three operating controls—TIME PER POINT, ±VOLTS, and TRIG LEVEL—can be compared to the scope sweep speed, vertical gain, and sweep trigger controls respectively. Signals can be sampled up to 500 kHz (2 µs) producing 256 data points, enough to make a very smooth waveform. This sampling can be selected in 1-2-5 steps from 2 µs to 100 ms, via the crystal-controlled internal clock or an external clock. Input sensitivity is

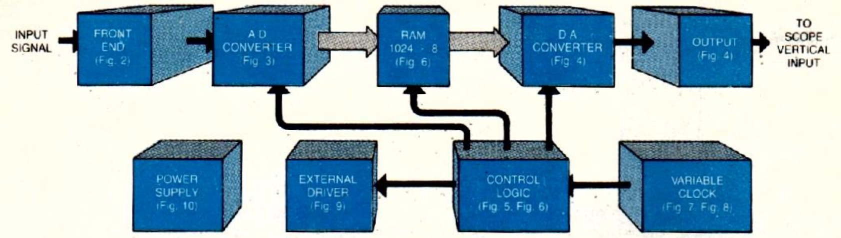


Fig. 1. Block diagram of the Wavesaver system from the input signal to the scope's vertical input.

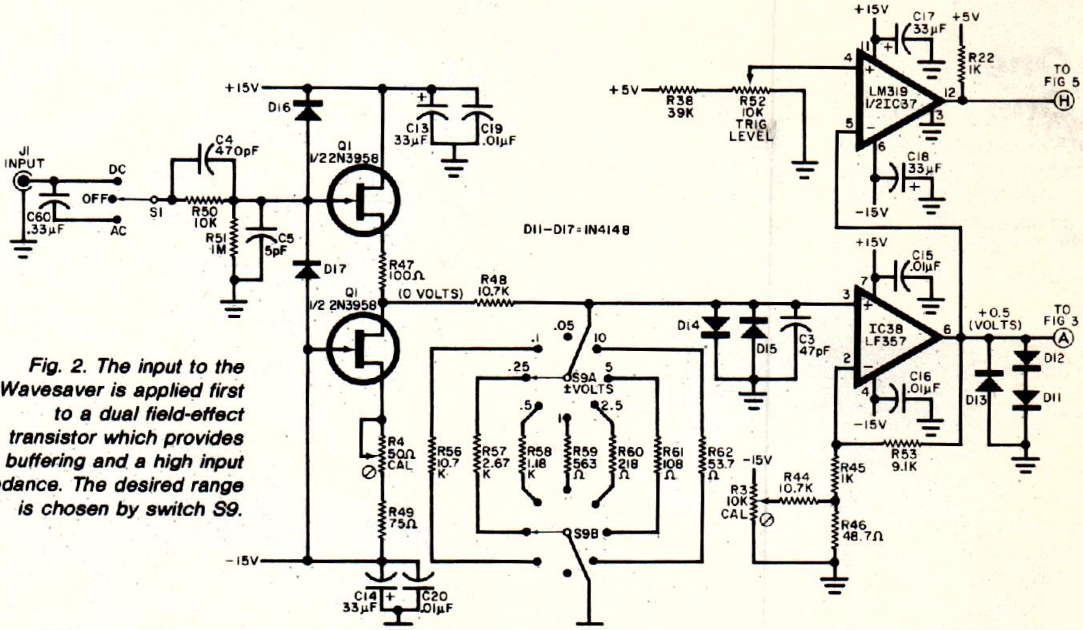


Fig. 2. The input to the Wavesaver is applied first to a dual field-effect transistor which provides buffering and a high input impedance. The desired range is chosen by switch S9.

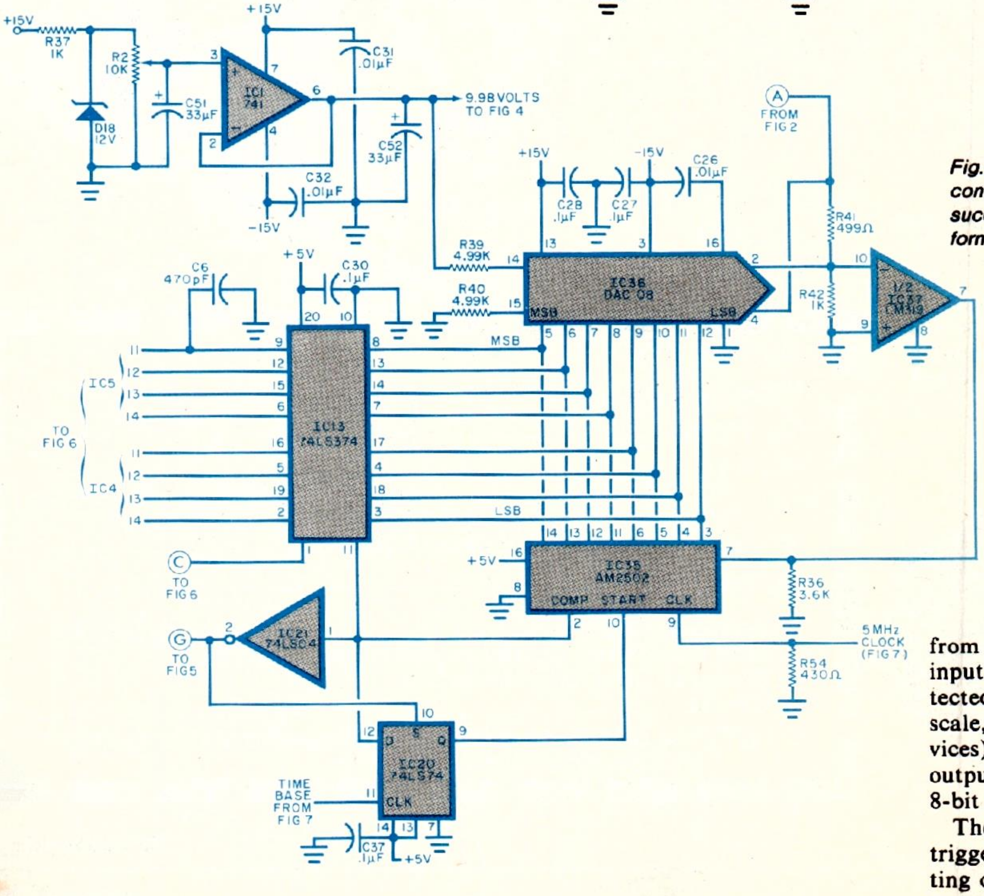


Fig. 3. The analog/digital converter is an 8-bit successive-approximation circuit formed by IC35 and IC36.

from 50 mV to 10 volts at one-megohm input impedance and is overload protected. The analog output is 8 volts full scale, trigger output (for external devices) is at TTL level, and the digital output for the external digital system is 8-bit parallel, TTL, word serial.

The Wavesaver has three different triggering modes. The first uses the setting of the front-panel TRIG LEVEL control to preset an input level and polarity that, when the viewed signal exceeds se parameters, the system starts storing data. In this mode the system can monitor ("babysit") a signal line, allowing you to leave the equipment and go about other business. If the event occurs during your absence, it will be recorded. At your convenience you can "see" what went on before the event, the event itself, and a short period after the event. This is great for observing "glitches."

The second trigger mode, AUTO, updates the stored data every two seconds. The stored image can be "frozen" on screen as long as the user desires. In the third trigger mode, the system is operated manually via a front-panel pushbutton. The data remains on screen until the manual pushbutton is depressed. This is ideal for detailed study of a waveform of interest.

The digital storage technique used in the Wavesaver allows direct connection to a computer for further signal processing, or storage on a diskette. The data can also be passed to a plotter that can generate permanent records for later study.

Circuit Description. As shown in Fig. 2, the signal to be observed is applied via ac/dc input selector switch *S1* to dual FET *Q1* that provides input buffering and a high input impedance (1 megohm). Potentiometer *R4* determines the zero offset, while diodes *D16* and *D17* protect the input stage against excessive

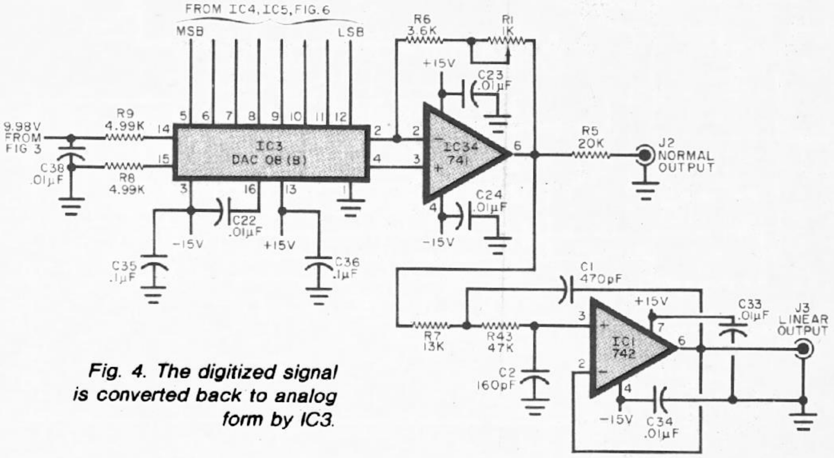


Fig. 4. The digitized signal is converted back to analog form by IC3.

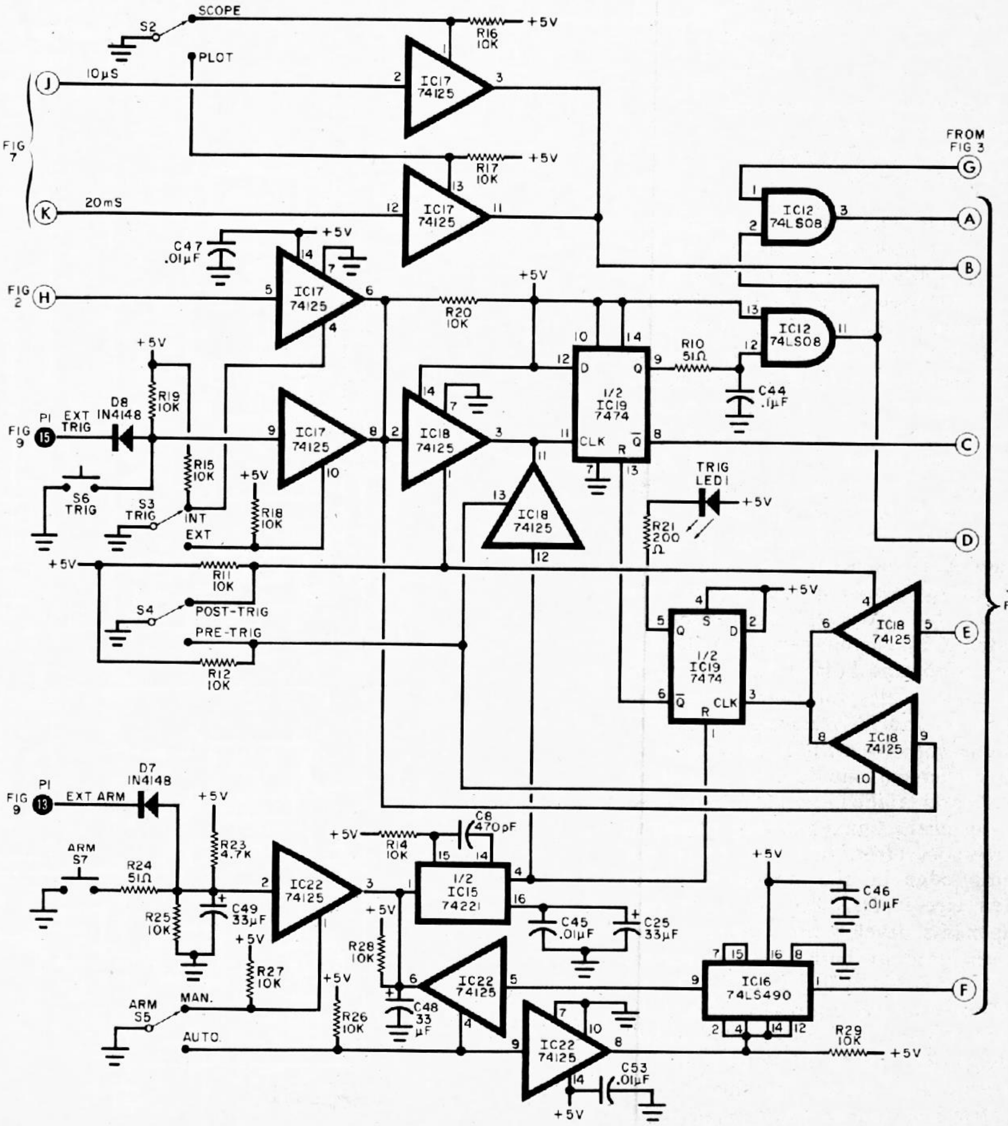


Fig. 5. The control logic is shown here and in Fig. 6 on the next page. The combination of IC18 and IC19 supplies the actual start and stop signals of the recording mode.

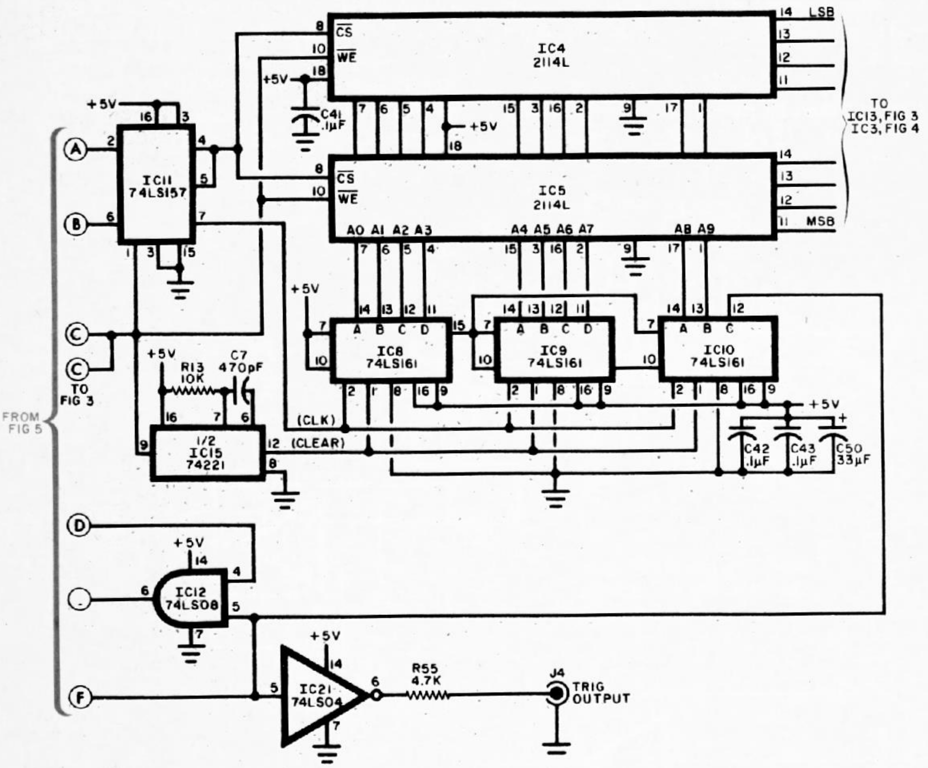


Fig. 6. Random-access memory is contained in IC4 and IC5, with IC8, IC9, and IC10 serving as address counters.

signal levels. The network consisting of *R48* and a resistance selected by the ±VOLTS switch (*S9*) provides the desired signal input range. Diodes *D14* and *D15* protect the *IC38* input against damage from high-level signals. The signal is amplified in *IC38* to provide the A/D converter (Fig. 3) with the correct levels, while diodes *D11* through *D13* act as level clamps to protect the A/D converter. The output of *IC38* also drives half of *IC37*, to provide the trigger signal for the control logic (Fig. 5).

The A/D converter of Fig. 3 is an 8-bit successive-approximation type formed by successive-approximation register *IC35*, current-sensing A/D converter *IC36*, and half of *IC37*. It takes nine clock cycles for each conversion, with *IC21* and *IC20* acting as a start/stop enabling circuit. On completion of each conversion, the data at the output of *IC35* and latched into *IC13* on the rising edge of the signal and then passed to the memory (*IC4, IC5*, Fig. 6) on the trailing edge of the waveform. Integrated circuit *IC1* and its associated components develop the reference current required by both D/A converters (*IC36* and *IC3*). In Fig. 6, *IC8, IC9* and *IC10* serve as the address counters for RAMs *IC4* and *IC5*, and are "clocked" by *IC11*. Pin 12 of *IC10* generates a "memory full" signal for the system, and after inversion by a portion of *IC21*, supplies the "sync" signal for the oscilloscope.

Selection of the Wavesaver's display or record mode is determined by the state of *IC11* (Fig. 6). An element within *IC17* (Fig. 5) selects either the SCOPE or PLOT mode via *S2*, while another element within *IC17* operates in conjunction with TRIGGER switch *S3* to determine whether INT or EXT triggering was selected. The combination of *IC18* and *IC19* supplies the actual start and stop signals of the recording mode. A dual-decade counter (*IC16*) provides the auto-arm function and disables the manual-arm feature (Fig. 5).

The crystal-controlled clock oscillator is formed by elements of *IC28* and its 5-MHz output is used to clock the A/D converter (Fig. 7). It also drives a chain of eight decade counters (*IC23* through *IC26*, and *IC29* through *IC32*) arranged in a 1-2-5 sequence to produce time pulses from 2 µs to 100 ms. Multiplexers *IC27* and *IC33* of Fig. 8 accept these timing signals while the 16-position TIME PER POINT switch (*S10*) determines the sampling rate.

To display the stored waveform on a

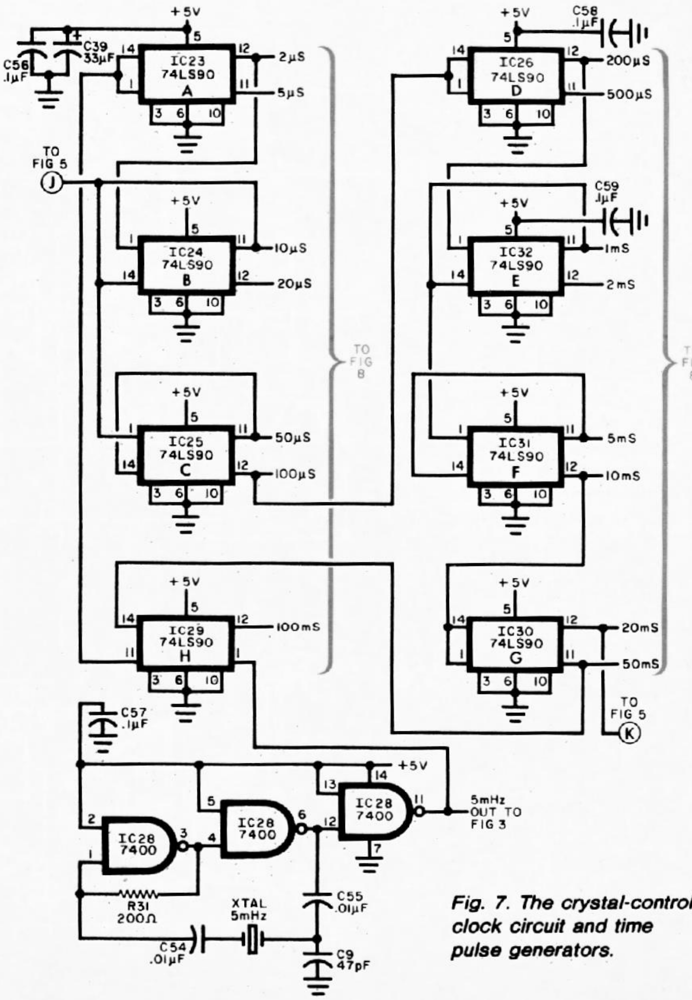


Fig. 7. The crystal-controlled clock circuit and time pulse generators.

scope, requires that the digitized signal be converted back into analog form. This is the purpose of *IC3* in Fig. 4. This chip accepts an 8-bit digital data stream from the RAM and, using a fixed reference voltage, generates the analog equivalent at its output. (Since the D/A converter is a "current" device, *IC34* is used as a current-to-voltage converter.) A simple active filter (*IC2*) smooths the reconstructed waveform. The digitized signal, as well as certain "handshake" signals, are also available from connector *P1* (Fig. 9). The digitized signal is buffered by *IC6* and *IC7*, with the handshake signals available for flexibility when direct interfacing with external digital devices is involved. The power supply is shown in Fig. 10.

Construction. It is recommended that the Wavesaver be constructed using the dual-sided pc board shown in Figs. 11 and 12. Component installation is shown in Fig. 13, and external elements are connected as shown in Fig. 14.

To avoid possible static damage, mount *Q1* only after its associated components are installed. Rectifier diodes *D3* through *D6* are mounted on the underside of the board so that transformer *T1* can be properly installed. The dot on *T1* specified in the Parts List indicates pin 1, and sockets should be used for all semiconductors. After completion, the board can be mounted within a selected metal enclosure.

Other than *S9* (the ±VOLTS rotary switch mounted on the pc board to protrude through the front panel), switches *S3* through *S7* along with *LED1* (TRIG), *LED2* (POWER), and INPUT connector *J1* are mounted on the front panel of the selected enclosure. Each front-panel element should be identified with press-on type.

The three BNC output connectors—*J2* (NORM), *J3* (LIN), and *J4* (TRIG), along with *S2* (SCOPE/PLOT), fuse *F1*, and the power line cord should be on the rear panel of the enclosure. The 15-pin external connector *P1* should be mounted on the pc board to protrude through a slot cut in the rear panel.

Calibration. A high-input-resistance dc voltmeter (preferably a 3½-digit DMM), an oscilloscope, and an audio signal generator should be used to calibrate the Wavesaver. When power is applied, the POWER indicator (*LED2*) should glow. Check that 5-, 15-, and −15-volt supplies are delivering the correct voltages.

To set the reference level, connect the dc voltmeter between test point A (Fig. 13) and ground. Adjust *R2* for 9.92 volts (given as 9.98 on the schematics to com-

INSIGHTS TO DIGITAL STORAGE

There are two digitizing techniques that you shouldn't confuse: real-time sampling and equivalent-time sampling. Digital storage scopes use real-time sampling so that they can capture both repetitive and single-shot signals. Sampling scopes use equivalent-time sampling and are limited to capturing repetitive signals. Equivalent time sampling—random or sequential—builds up a picture of the input waveform by capturing a little bit of information during each signal repetition. Eventually enough information is available to reconstruct the entire waveform. Among the drawbacks of analog-type storage is fading or blooming of the recorded waveform, which does not exist with digital storage.

Accuracy vs. Resolution. The digital storage scope's A/D converter must be able to "resolve" (discriminate between) different input signal levels. Here, resolution is determined by the number of "bits" (binary digits) that will be used to approximate the analog input signal. For example, a 2-bit number that forms all combinations of 1 and 0 produces 11, 10, 01, and 00. If the analog input range to be measured is 10 volts, as shown in (A), the four possible sub ranges must be 0-2½, 2½-5, 5-7½, and 7½-10 volts (each bit will switch half way up its input level—not very smooth). Thus, the more bits, the better the resolution. In the Wavesaver's 8-bit converter there are 256 levels with each level representing 0.3906% of the input voltage, or 3906 parts per million.

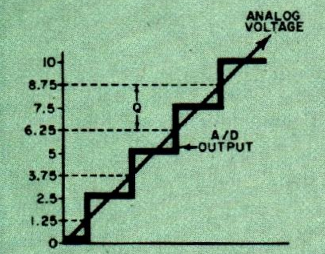


Fig. A. In an A/D converter, the analog input is sampled at the midpoint of each quantization level, the distance between levels being denoted by Q, the bit size.

Accuracy and resolution are not the same thing. Resolution is the distinguishing of individual elements, while accuracy is another term for repeatability—conformity to an indicated value with repeated measurements. For example, assume your DMM has just 3 digits (2½ digits if you're fussy). If you apply any level from 149½-150½ volts dc to it and the display always indicates 150 V, the resolution of this particular DMM is 1 volt. It cannot distinguish between smaller voltage differentials.

Accuracy, on the other hand, means that if you apply exactly 150 volts to the instrument, it should display 150 and nothing else. If you do apply exactly 150 volts, and the display indicates 147, the accuracy of the instrument is 2% (3 divided by 150) at 150 volts. Accuracy cannot be better than the resolution.

A Unique Error. Pushing a digital storage scope past its upper frequency limit results in an error different from that encountered with an analog scope used under similar conditions. The error is called aliasing, as illustrated in (B) and there is only one way to avoid it: always digitize more than twice as fast as the highest frequency in the analog input signal. If a suitable digitizing rate is not available, you can use an anti-aliasing filter to eliminate frequencies above the Nyquist limit. That avoids aliasing, but it also removes any indication that higher-frequencies are present in your input signal.

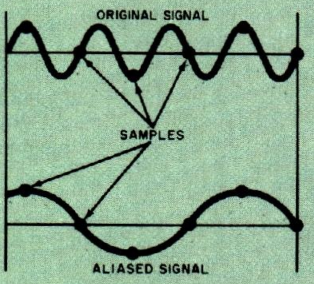


Fig. B. If a signal is digitized less often than necessary, aliasing results. Here a 120-Hz signal digitized at 160 Hz; gives an aliased waveform at 40 Hz.

Anti-aliasing filters have at least 12-dB/octave rolloff, while bandwidth-limiting filters are 6 dB/octave.

Once you know the maximum digitizing rate of a digital storage scope, you can determine if the instrument will meet your needs by applying sampling theory. Application of the theory shows that any signal with a frequency denoted by *f* must be digitized *more than 2f* times to be fully recovered (exactly two times won't do).

Another way of stating the same rule uses the Nyquist frequency (half the digitizing frequency). No frequency at or above it can be recovered without error.

Remember, a digital storage scope is not the same as a sampling scope. A digital storage scope captures the entire signal—be it repetitive or single occurrence—in one shot, while a sampling scope requires many "shots" at a *repetitive* signal before it can build up a usable image. Thus, a sampling scope cannot be used to observe non-repetitive random events, but it is not constrained by aliasing when examining high-frequency inputs. ◇

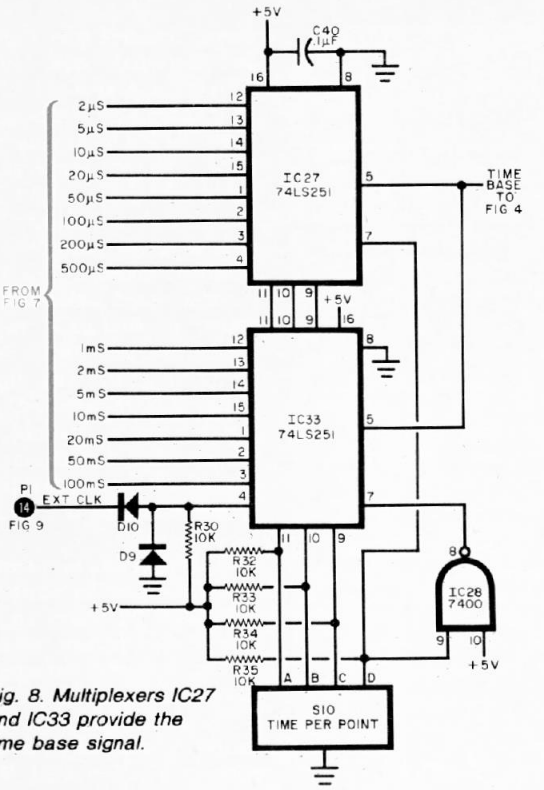


Fig. 8. Multiplexers IC27 and IC33 provide the time base signal.

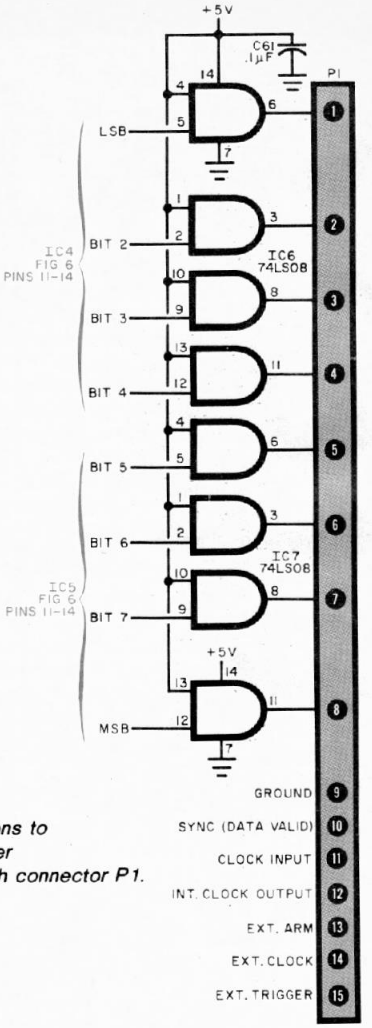
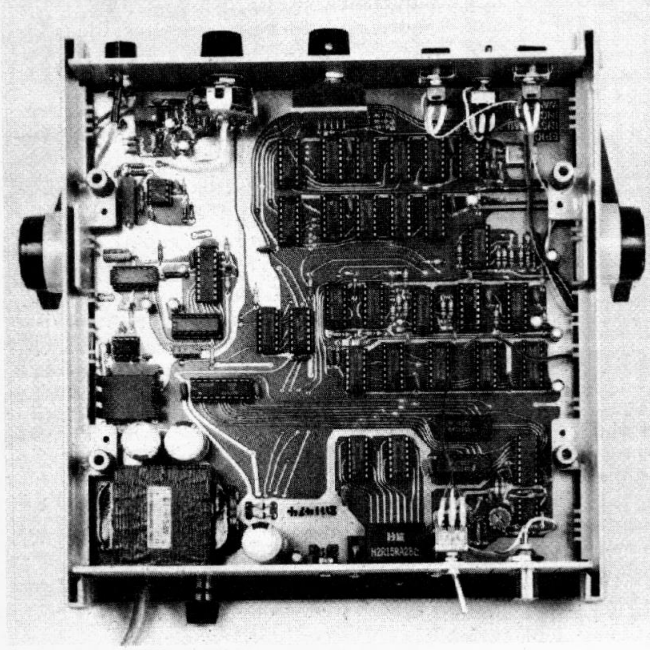


Fig. 9. Connections to the external driver are made through connector P1.



Internal view of the author's prototype Wavesaver

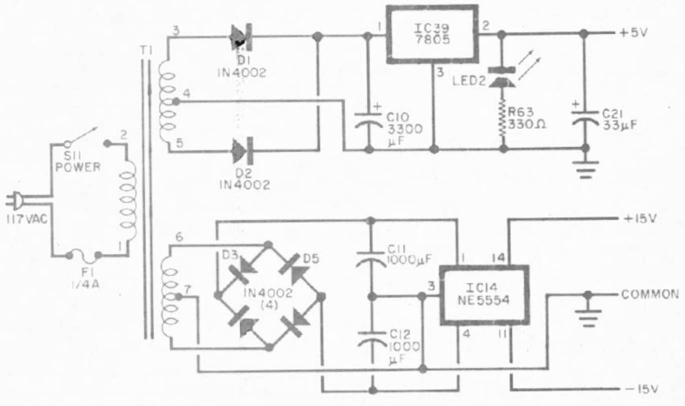


Fig. 10. Schematic of the power supply for the Wavesaver.

pensate for drifting due to heat). To zero offset *Q1* connect the dc voltmeter between test point B and ground. Adjust *R4* for zero. To adjust the A/D converter offset, connect the dc voltmeter between test point C and ground. Adjust potentiometer *R3* to obtain exactly 0.49 volt.

To set up the front panel, turn *S4* to POST TRIG, set ARM switch *S5* to AUTO, set TRIGGER switch *S3* to INT, and turn the INPUT selector switch *S1* to OFF (center) position. Now when TRIG LEVEL potentiometer *R52* is rotated, the TRIG LED indicator should blink on and off every two seconds.

With this LED blinking, set the TRIG LEVEL potentiometer to the center of its most sensitive area (where the LED blinks). Once this point is located, loosen the knob, place the knob index at the "0" scale marker, and then tighten the knob. Be careful not to disturb the potentiometer setting.

PARTS LIST

C1,C4,C6,C7,C8—470-pF, disc capacitor
C2—160-pF, disc capacitor
C3,C9—47-pF, disc capacitor
C5—5-pF, disc capacitor
C10—3300-μF, 25-V electrolytic
C11,C12—1000-μF, 25-V electrolytic
C15,C16,C19,C20,C22,C23,C24,C26,C31, C32,C33,C34,C38,C45,C46,C47,C53, C54,C55—0.01-μF disc capacitor
C27,C28,C30,C35,C36,C37,C40-C44,C56-C59,C61—0.1-μF disc capacitor
C13,C14,C17,C18,C21,C25,C29,C39,C48-C52—33-μF, 16-V electrolytic
C60—0.33-μF, 100-V capacitor
D1-D6—1N4002
D7-D17—1N4148
D18—12-V zener diode
F1—¼-A fuse
IC1,IC2,IC34—MC741N op amp
IC3,IC36—DAC08EP D/A converter, 8-bit
IC4,IC5—MM2114L 1K x 4 RAM
IC6,IC7,IC12—74LS08 quad 2-input AND
IC8-IC10—74LS161 4-bit binary counter
IC11—74LS157 quad 2-input data selector
IC13—74LS374 octal D flip-flop, 3-state
IC14—NE5554N dual polarity regulator
IC15—74221 dual mono multivibrator
IC16—74LS490 dual BCD decade counter
IC17,IC18,IC22—74LS125 quad 3-state buffer
IC19—7474 dual D flip-flop
IC20—74LS74 dual D flip-flop, low power
IC21—74LS04 hex inverter
IC23-IC26,IC29-IC32—74LS90 decade counter
IC27,IC33—74LS251 8-input multiplexer
IC28—7400 quad 2-input NAND
IC35—DM2502 8-bit successive approximation register.
IC37—LM319N high-speed dual comparator
IC38—LF357N bi-fet op amp
IC39—MC7805 5-volt regulator
J1-J4—BNC connector
LED1,LED2—Red light-emitting diode
P1—15-pin PCB "D" connector (Holmberg H2R15RA28C or similar)
Q1—2N3958
The following are 5%, ½ or ¼-W resistors unless otherwise specified:
R1—1000-Ω trimmer potentiometer
R2,R3—10 kΩ, 15-turn trim potentiometer (Bourns 3006P or similar)
R4—50 Ω, 15-turn trim potentiometer (Bourns 3299 or similar)
R5—20 kΩ
R6—3.6 kΩ
R7—13 kΩ
R8,R9,R39,R40—4.99-kΩ, 2%
R10,R24—51 Ω
R11-R20,R25-R30,R32-R35,R50—10 kΩ
R21,R31—200 Ω
R22,R37—1 kΩ
R23-R55—4.7 kΩ
R36—3.6 kΩ
R38—39 kΩ
R41—499 Ω, 2%
R42,R45—1 kΩ, 2%
R43—47 kΩ
R44,R48,R56—10.7 kΩ, 2%
R46—48.7 Ω, 2%
R47—100 Ω, 2%
R49—75 Ω, 2%
R51—1-megohm
R52—10 kΩ, linear taper potentiometer
R53—9.1 kΩ
R54—430 Ω
R57—2.67 kΩ, 2%
R58—1.18 kΩ, 2%
R59—563 Ω, 2%
R60—218 Ω, 2%
R61—108 Ω, 2%
R62—53.7 Ω, 2%
R63—330 Ω
S1—spdt, center-off switch
S2-S5,S8—spdt switch
S6,S7—N.O. pushbutton switch (C&K-8531J81ZQZ2-2)
S9—8-position, single pole, rotary switch
S10—16-position, rotary switch, BCD encoded (AMP 435987-1 or similar)
S11—spst switch
T-1—signal MPC-Y-12 (suitable for +5V@835 mA, ±12V@150 mA)
Misc.—15/16″ diameter knobs (2), ½″ diameter knob; IC sockets, fuseholder, line cord, enclosure, (PACTEC CH23K or similar), mounting hardware.

NOTE: The following is available from Epic Instruments Inc., 551-G Foster City Blvd., Foster City, CA 94404: complete kit of all parts including pc board, front/rear panels, enclosure, assembly manual and operation manual at $228.00. Also available separately: DAC08EP at $2.80 each; NE5554N at $1.50; DM2502 at $7.45; LM319N at $1.95; LF357N at $1.45; 2N3958 at $1.60; 5 MHz crystal at $4.00; signal MPC-Y-12 at $15.00; 1k trimpot at $.75; two 10k trimpots at $3.10; 50-ohm, 15-turn at $2.50; 10k potentiometer at $2.00; two C&K-8531J81ZQZ2-2 switches at $4.80; 8 position rotary switch at $2.00; AMP-435987-1 at $8.82; Front/Rear panel set—punched, silk screened, and anodized at $16.00; PACTEC—CH23K at $32.23; pc board—double sided with plated through holes and solder mask at $36.00. Add $3.00 shipping and handling for all orders. California residents, add 6½% tax.

Next, use the scope to set the audio signal generator for a 50-mV peak-to-peak output at 1-kHz using either a sine or a triangle waveform. Connect NOR OUTPUT (*J2*) to the scope's vertical input, and connect the TRIG OUTPUT (*J4*) to the scope's external trigger input. Set the scope on external trigger with the vertical attenuator for 2V/division, and the sweep selector to 1 ms/div.

On the Wavesaver, adjust the ±VOLTS switch to 50 mV and the TIME PER POINT to 2 ms. Connect the audio signal generator to input *J1* and place input selector switch *S1* in the ac position. A signal trace should appear on the scope. Use the scope's vertical and horizontal controls to center the trace. Adjust *R1* (Fig. 11) on the Wavesaver's pc board for exactly four divisions on the scope graticule.

Display Interpretation. The Wavesaver's controls provide adjustments that are similar but not identical to those found on a conventional oscilloscope. For example, the TIME PER POINT selector is somewhat like the conventional scope's sweep selector. This new control name is used because the Wavesaver samples the input waveform at intervals selected by the TIME PER POINT selector switch, disregarding the time between sample intervals. The digital data is then stored within the internal 1K by 8-bit RAM. However, in every display, the full 1K bytes of RAM will be displayed.

Reading the regenerated display is similar to reading a conventional scope, screen. For example, assume that one period (T) of a regenerated waveform occupies the full screen width. If the TIME PER POINT SWITCH is set to 5 μs, then one full sweep is 1024 x 5 μs or 5.12 ms (essentially 5 ms). Since f = 1/T, the displayed waveform's frequency is 1/5 ms or 200 Hz.

Operation. The Wavesaver has two basic modes of operation—pre-trigger and post-trigger. In the former, whatever digitized data is in the RAM is captured when the trigger signal is applied. In the post-trigger mode, the RAM captures data after the trigger is applied.

Pre-Trigger Mode:

1. Place the ARM toggle switch (*S5*) in the MAN position.
2. Place the TRIGGER toggle switch (*S3*) for either INT or EXT.
3. Select the desired TIME PER POINT (*S10*), ±VOLTS (*S9*), INPUT coupling (*S1*) for either ac or dc, and adjust TRIG LEVEL (*R52*) if INT triggering is selected. Potentiometer *R52* works in conjunction with the ±VOLTS selector with the 0 position approximating ground.

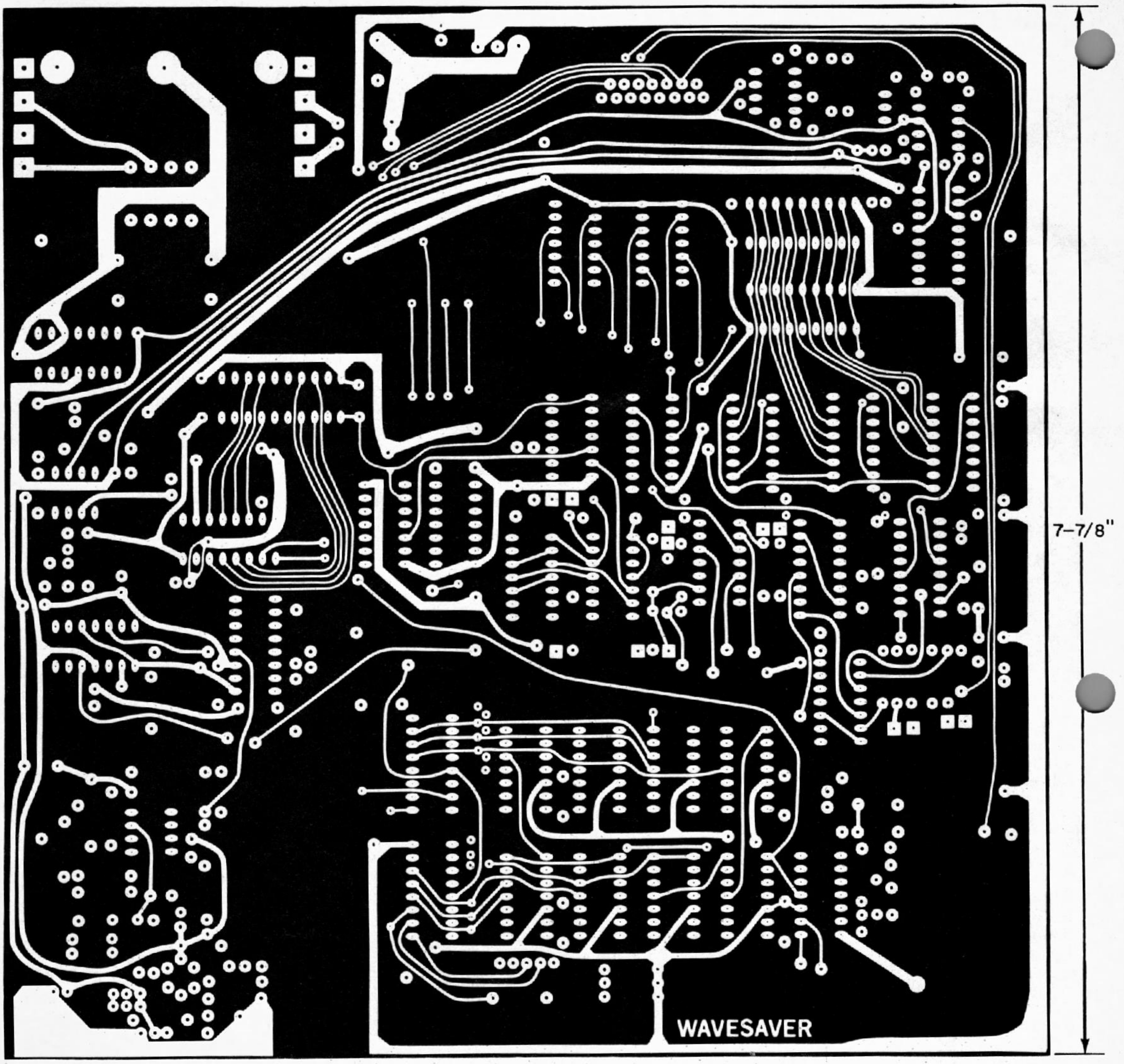


Fig. 11. Reduced pattern for foil side of the double-sided pc board. Note correct size.

4. Use either the ARM pushbutton switch (*S7*) or pin 13 of the rear panel *P1*. *LED1* above the TRIG LEVEL control should glow if arming is successful.

5. After arming, the data recording process will begin instantly and can be stopped only by triggering the system.

6. If INT trigger was selected, after the correct signal level (determined by the TRIG LEVEL control) is detected, the system will trigger automatically. If EXT trigger was selected, the system has to be triggered either manually with the TRIG pushbutton (*S6*), or via pin 15 of *P1*. After detecting the trigger, the data recording will stop immediately.

7. If the ARM toggle switch is in the AUTO position, the system will be automatically armed after two seconds of display time elapses. If it is desired to "hold" a waveform, flip the ARM toggle switch to the MAN position before the two-second interval has elapsed.

8. During pre-trigger recording, if the trigger occurs before the entire sweep of the memory has elapsed, the display might include a portion of the previously recorded waveform if not erased. To erase the memory, place the TRIGGER toggle switch in the EXT position before arming and after the time interval determined by 1024 times the setting of the TIME PER POINT switch. After erasing, place the TRIGGER switch back to the desired position.

Post-Trigger Mode:

1. Select the desired TIME PER POINT, ± VOLTS, TRIG LEVEL (if INT trigger is selected), INPUT coupling, and either MAN or AUTO arm (as required).

2. If MAN arm is selected, use either the front-panel ARM pushbutton or pin 13 of *P1*.

3. After detecting the trigger, the recording will begin, and after the RAM has accepted one full sweep, the system will go to the display mode. Until a new ARM signal is applied, the data just

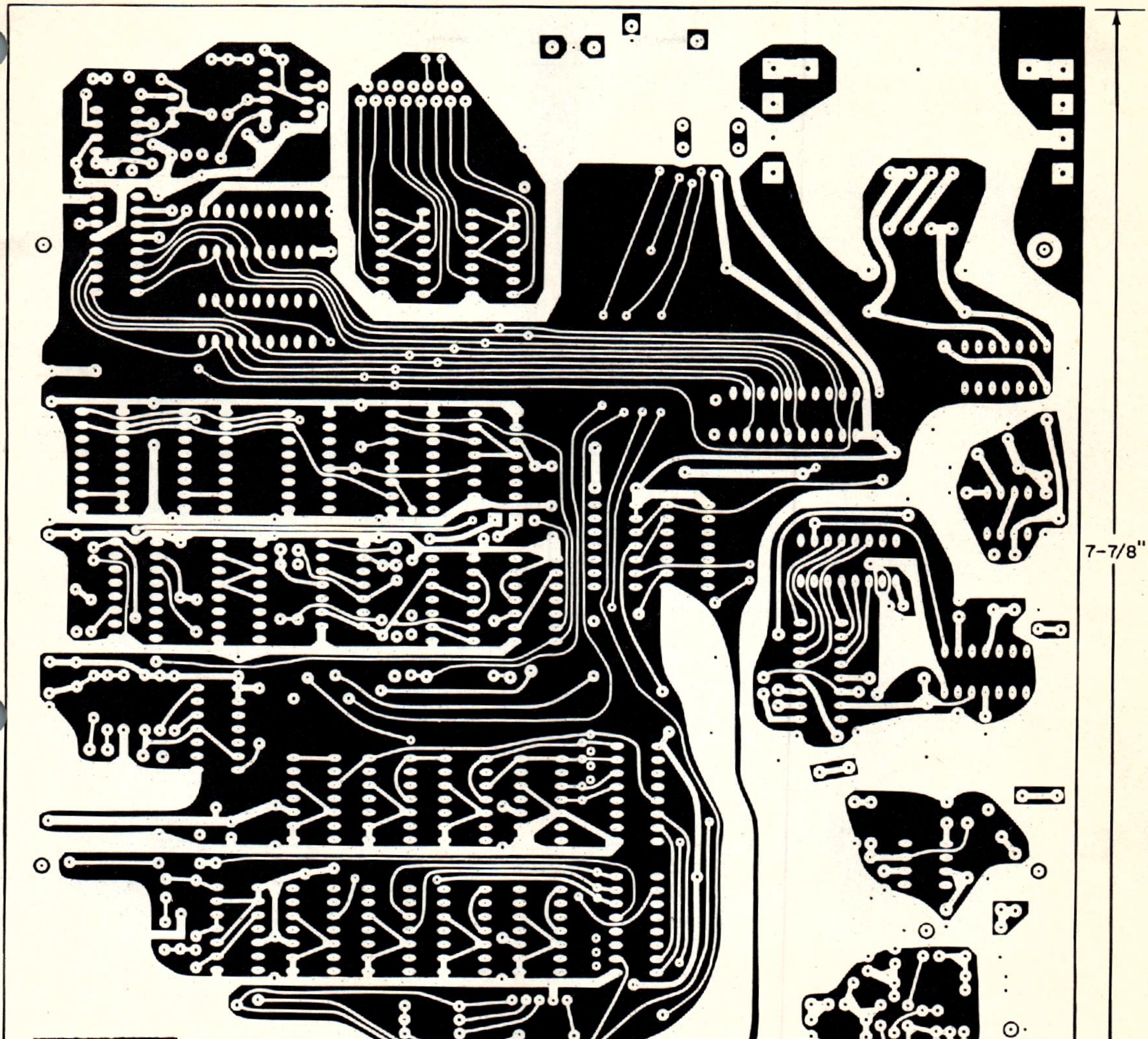


Fig. 12. Reduced foil pattern for component side of pc board. Note correct size.

stored in the RAM will be continuously displayed.

4. In the AUTO arm mode, the system arms itself after displaying the data stored in the RAM for two seconds. After two seconds, any new trigger will automatically initiate updating the RAM with new data.

5. To retain a waveform when operating in the AUTO mode, place the ARM toggle switch in the MAN position.

Waveform Voltage Level:

1. Although the ± VOLTS switch can be set as desired, the analog output level of the Wavesaver is always 8 volts for a full-scale display.

2. If the recorded waveform measures two graticule divisions, the scope vertical sensitivity is set at 2 V/division, and the ± VOLTS switch is set at 0.5 volt, the recorded signal has an amplitude of 0.5 volt.

Plotter Use:

1. When SCOPE/PLOT switch *S2* is placed in the PLOT position, this enables connector *P1*.

2. On *P1*, pins 1 through 8 are digital data with pin 1 the most significant bit and pin 8 the least significant bit. Pin 9 is ground, pin 10 is sync (or data valid), pin 11 is the input for an external clock, and pin 12 is a 50-Hz pulse that can be used as the "write" pulse to an external computer. If the Wavesaver's internal clock is used, pin 11 and pin 12 must be shorted together. Pins 13 through 15 are external inputs for remote arming, triggering, and then clocking data into memory. All signals to *P1* must be TTL, and pins 1 through 8 can drive three 74LS (low-power Schottky) loads.

Applications. Uses for a storage oscilloscope are many. The test instrument presented here, for example, enables the user to see events before triggering. This is useful in solving a variety of problems before they would normally occur, such

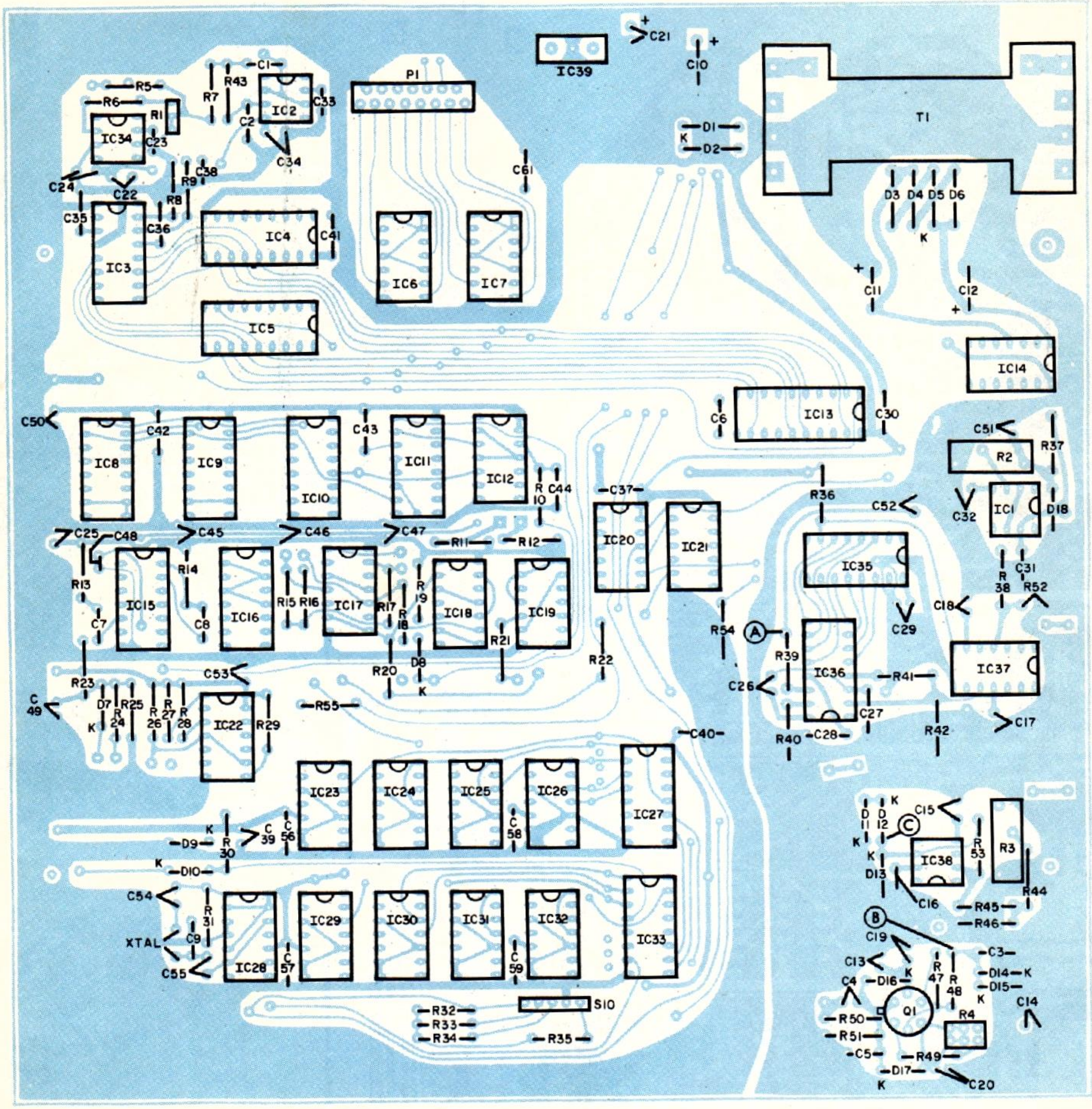


Fig. 13. Component layout for the pc board.

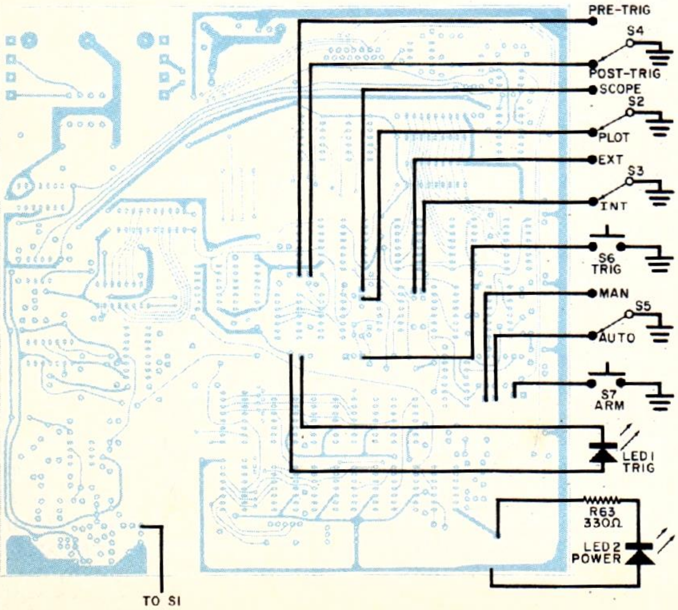


Fig. 14. Connections to external components from the pc board.

as witnessing a glitch that blows a fuse. With post-trigger only, it would be too late. You can record events while you're out having a cup of coffee, since the instrument has an automatic mode. In the manual mode, you can catch those fleeting one-shots. And the digital output interface enables you to plug in the stored information to a computer for analysis.

Here's a sampling of applications: switch-bounce testing, microphone performance, speech synthesis, loudspeaker analysis, television servicing, audio system testing, automotive engine performance, logic-circuit testing, capacitor characteristics, and so on. Clearly, the Wavesaver can open up new horizons on your test bench. ◇