WAV1
Waveform Generator Module

Introduction

The WAV1 Waveform Generator Module provides one channel of sine, square or triangle waveform output. The module is comparable to a standard function generator in which the adjustment knobs and switches have been replaced by programmable D/A converters and software switches. The main WAV1 functions of frequency, duty cycle (symmetry), amplitude and DC offset are programmable to 1 part in 4096 (12-bit resolution). Output voltage range is switch-selectable at 1V or 10V.

The WAV1's output waveform is available on a standard BNC connector. The main output as well as TTL-level trigger outputs are also available from an on-board screw terminal block.

Available frequencies cover 0.1Hz to 200KHz in six decade-weighted ranges. Accuracy is typically 5% of setting (10% on 2Hz and 20Hz ranges). For optimum accuracy, the WAV1 should be operated in the upper 90% of any given frequency range. Amplitude accuracy is 5% (to 20V P-P into 500 ohms). Peak output current is 20mA. The WAV1 duty cycle is programmable from 5% to 95%. Sine wave distortion is typically less than 3%.

The WAV1 includes a selectable synchronous stop feature. Synchronous stop allows the waveform output to complete the current output cycle, even though the WAV1 output may have been disabled before this point. Alternately, the WAV1 output can be set up to return to 0 immediately when the output is disabled. A waveform always starts at the lowest amplitude point of the triangle and sine waves.

DC output and offset function may be used to bias output waveforms. Alternately, the WAV1 may be used as a general-purpose bipolar bias source of ±10V at 20mA. The WAV1 can also be used to pace the conversion rate of the AMM1A or AMM2 modules at rates other than those provided by the AMM module crystal oscillator.

Hardware Compatibility

The WAV1 can be operated in slots 2 through 10 of the 500A or 500P mainframe, or in the option slot of the Model 570 or 575. If the WAV1 will be used to control an AMM module via its trigger input, the AMM module must have PAL revision D or later. If an AMM1A or AMM2 is not resident in the system, resistor R53 must be installed on the WAV1 to supply a system reference voltage.

Software Compatibility

All WAV1 functions can be accessed by writing control information directly to the WAV1's slot-dependent Command A (CMDA) and Command B (CMDB) registers. These functions include frequency, duty cycle, range, function, amplitude, offset, synchronous stop enable/disable, and global strobe enable/disable.

Control can also be exercised through any high- or low-level language which permits writes to memory addresses (e.g. BASIC POKEs). The WAV1 registers are write-only. See the WAV1 register map information later in this manual.

If you are using third-party software, be certain that the software is compatible with the WAV1.

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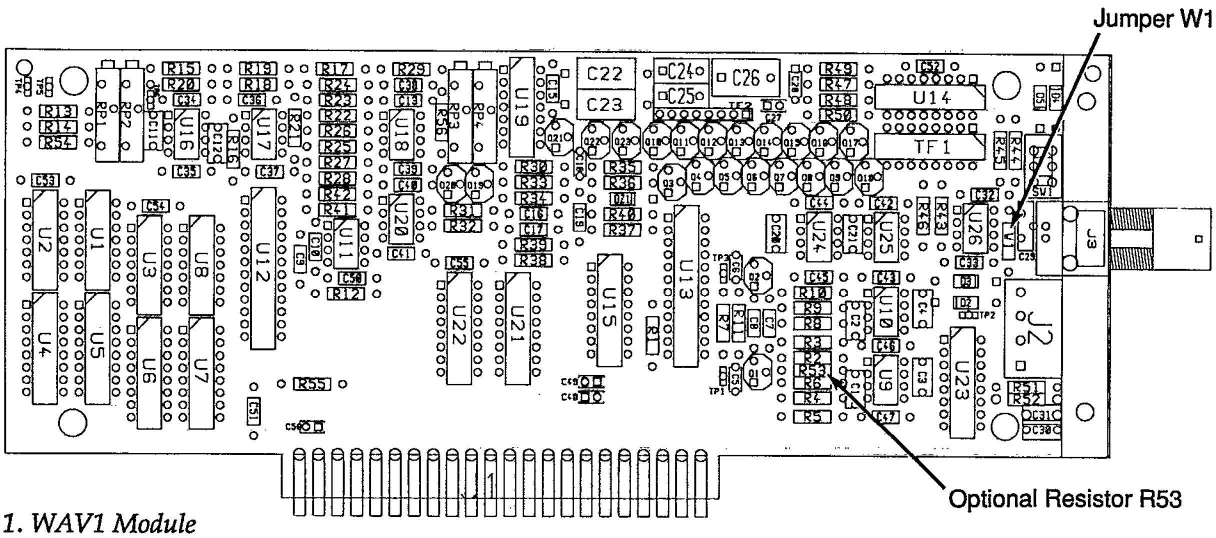


Figure 1. WAV1 Module

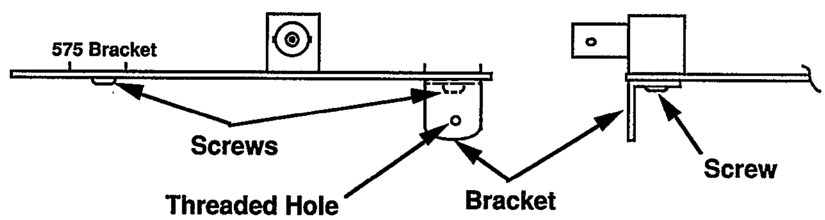


Figure 2. Model 575 Mounting Bracket

Specifications

Programmable Features:

Functions: waveform, frequency, amplitude, duty cycle, DC offset, haver waveforms.

Waveforms: sine, square, triangle, pulse, or DC output.

Frequency: 0.1Hz to 200kHz in six overlapping ranges.

Frequency ranges: 2, 20, 200, 2k, 20k, 200k Hz

Frequency resolution: 12 bits (1 part in 4096)

Frequency accuracy: (upper 90% of range) ±5% of setting, except ±10% on 2kHz and 20kHz ranges.

Amplitude ranges: 1V, 10V peak, switch selectable

Amplitude resolution: 12 bits (1 part in 4096)

Amplitude accuracy: ±5% of setting to 50kHz[1]

Offset ranges: ±1V, ±10V (tied to amplitude ranges)

Offset resolution: 13 bits (12 data + 1 polarity)

Offset accuracy: (5% of setting + 10mV)[1]

Maximum output: ±10V (20V p-p) into 500Ω, 20mA

Waveform symmetry: 5% to 95% (duty cycle) to 100kHz

Sine wave distortion: 1st harmonic down 35dB

Square wave rise time: 1μs

Triangle linearity: <3% error

[1] Total error is the sum of amplitude and offset errors. For DC-only operation, set waveform amplitude to 0 and use offset error, only.

Sync output: high and low true, TTL level, μs pulse width. Sync pulse occurs at minima of sine and triangle waves, or at falling edge of square wave.

General:

Operating temperature: 0°C to 70°C, 80% RH non-condensing down to 35°C

Storage temperature: -25°C to 80°C

Power-up condition: 0V output

Power consumption: 65mA for 5V digital, 85mA for ±15V analog

Signal connections: BNC for main output, quick-disconnect screw terminals for main and sync output.

Accessories: 2 ft. BNC to BNC cable, Model 7051-2, 3 ft. BNC to BNC cable, Model 7054-3

Installation

The WAV1 can be placed in any slot in the system. If the trigger output is to be used to control the operation of an AMM or TRG1 module, the WAV1 must be placed adjacent to that module, in the next higher-numbered slot.

CAUTION
Turn off power to the data acquisition system before you insert or remove any module. To minimize the possibility of EMI radiation, always operate the data acquisition system with the cover in place and properly secured.

CAUTION
Make sure you have discharged any static charges on your body before handling the module. You can do this most easily by simply touching the chassis of a computer or data acquisition mainframe which is plugged into a grounded, 3-wire outlet. Avoid touching components or the card edge connector of the module.

For a compatible multi-slot data acquisition system (Model 500A, 500P), remove the top cover of the system by loosening the cover retaining screws located in the upper corners of the rear panel. Slide the cover back about one inch and then lift it off. Insert the module in the desired slot with the component side facing the system power supply. Replace the system cover.

For a Model 570, install the module in the option slot with the component side of the board facing upward. Close and secure the cover.

For a Model 575, first attach the supplied right-angle bracket to the module (see Figure 2). Plug the module into the option slot with the components facing upward, and secure the bracket to the rear panel of the system. Close and secure the cover.

Connections

The output waveform is available on a standard BNC connector or from outputs on a screw terminal block.

A quick-disconnect terminal block can be removed from the module to facilitate making connections. Pull the block straight off the board with a firm, even pressure. Do not pry the terminals with a screwdriver or sharp object, or you may damage the circuit board.

Each individual terminal consists of a small metal block with a wire receptacle containing a metal compression tab. To make connections to a terminal block, first strip 3/16 of insulation from the end of the wire which you want to attach. Loosen the desired terminal screw on the block and insert the bare end of the wire into the corresponding receptacle. Tighten the screw securely to compress the tab against the wire.

After you have attached all the desired signal wires to a terminal block, replace the block by lining it up with the mating pins on the module and pressing it back into place.

Table 1. WAV1 User-Configured Components

Name	Desig.	Function
Jumper W1	W1	Series termination
Quick Disconnect	J2	Output & trigger conn.
BNC	J3	Coax output conn.

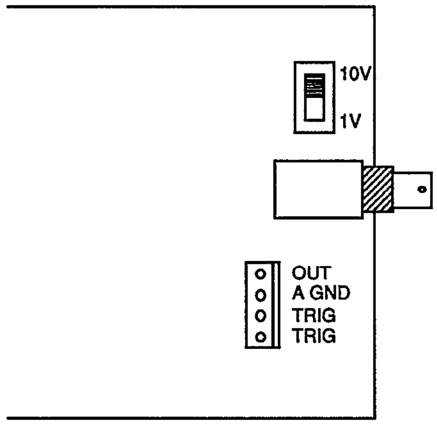


Figure 3. WAV1 Connections

NOTE
To minimize the possibility of EMI radiation, use shielded cable for the WAV1 output.

Output Limitations

There are certain restrictions as to the output capability of the WAV1. The output load should be greater than 500Ω with less than 100pF of shunt capacitance. The load resistance can be reduced if the peak output current does not exceed 20mA (i.e. 1V into 50Ω).

Jumper W1 is provided to enable the user to add a series resistance to match the characteristic impedance of the WAV1's output to that of the cable and load. The addition of a series resistor can also provide a higher degree of amplifier output protection. However, the resistance will increase source impedance and can thus decrease output amplitude. If the output load capacitance exceeds 100pF (50 ohm coax adds 30pF/foot) W1 should be replaced with a minimum 100Ω resistor to prevent output amplifier stability problems or spurious oscillations.

Command Locations

The WAV1 is controlled by writing to the Command A (CMDA) and Command B (CMDB) addresses for the slot in which the module is mounted. Programmable parameters include function, range, frequency/duty cycle, amplitude, and offset. Refer to your data acquisition system hardware manual for the addresses associated with the slot where the module is mounted.

Table 2. Slot-Dependent Memory Locations (hex)

	500, 570, 575		GPIB	
SLOT	CMDA	CMDB	CMDA	CMDB
1*	xxx80	xxx81	0	1
2	xxx82	xxx83	2	3
3*	xxx84	xxx85	4	5
4	xxx86	xxx87	6	7
5	xxx88	xxx89	8	9
6	xxx8A	xxx8B	A	B
7	xxx8C	xxx8D	C	D
8**	xxx8E	xxx8F	E	F
9	xxx90	xxx91	10	11
10	xxx92	xxx93	12	13

*=Model 575 Physical (Option) Slots
**=Model 570 Option Slot
xxx=First three digits of IBIN address, e.g. "CFF"

Table 3. WAV1 Command Locations and Functions

Read Functions:

COMMAND	FUNCTION
CMDA	None
CMDB	None

Write Functions:

COMMAND	FUNCTION
CMDA	Select Control Register
	Offset Polarity
	Data high nibble
CMDB	Data low byte
xxx9D	Global Strobe

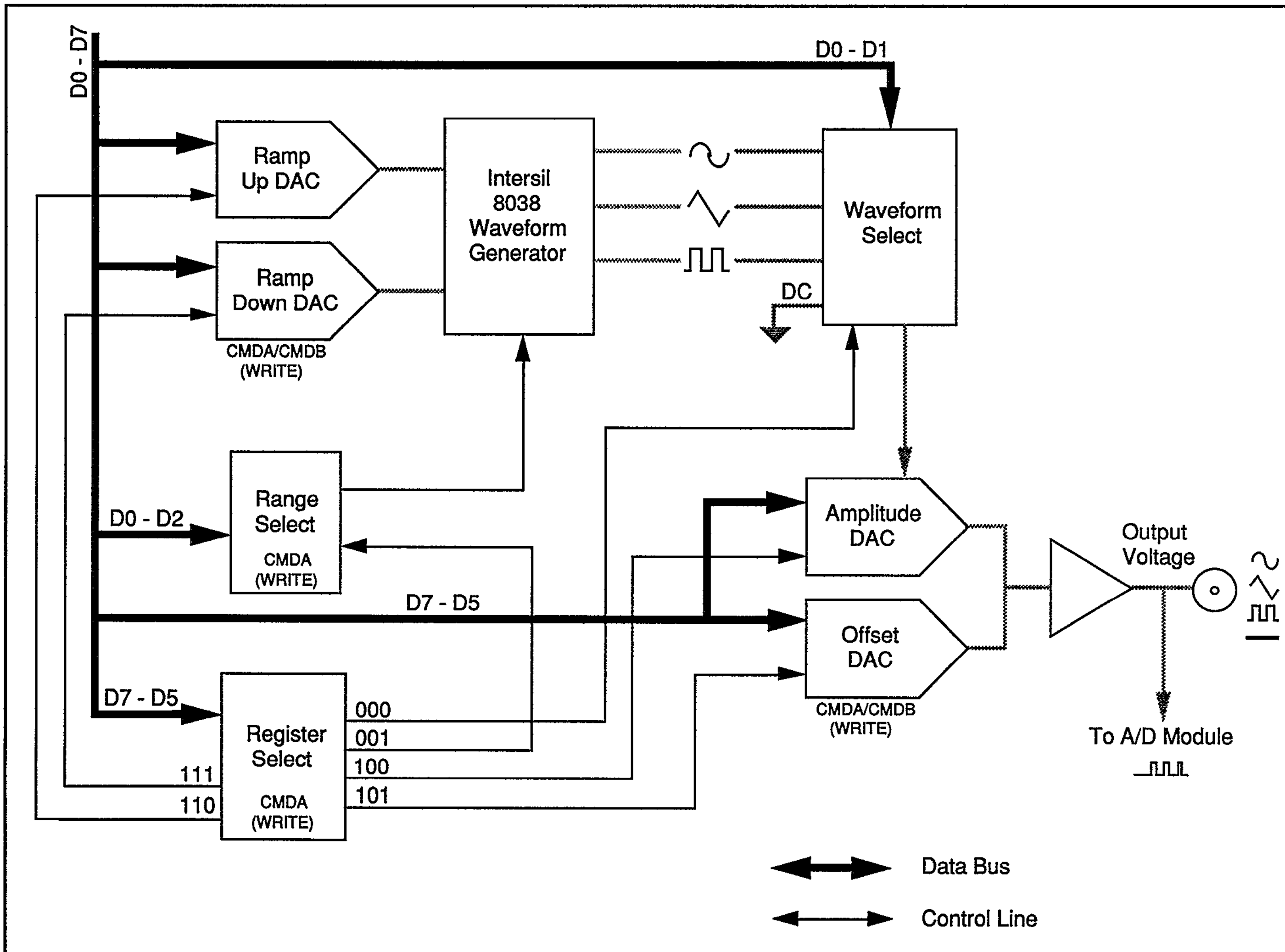


Figure 4. WAV1 Block Diagram and Register Functions

Control / Data	Data

SET FUNCTION :

CMDA

D7	D6	D5	D4	D3	D2	D1	D0
0	0	0					

Register Select

0

CMDB (not used)

D7 D6 D5 D4 D3 D2 D1 D0

- D1 D0 — Function Select : 00 - DC
- Function Select : 01 - Sine
- Function Select : 10 - Triangle
- Function Select : 11 - Square
- D2 — Output : 0 - Disable, 1 - Enable
- D3 — Sync Stop : 0 - Disable, 1 - Enable
- D4 — Not used

SET RANGE :

CMDA

D7	D6	D5	D4	D3	D2	D1	D0
0	0	1					

Register Select

1

CMDB (not used)

D7 D6 D5 D4 D3 D2 D1 D0

- D2 D1 D0 — Range Select : 000 - 200 kHz
- Range Select : 001 - 20 kHz
- Range Select : 010 - 2k Hz
- Range Select : 011 - 200 Hz
- Range Select : 100 - 20 Hz
- Range Select : 101 - 2 Hz
- Range Select : 110 - Not used
- Range Select : 111 - Not Used
- D3 — Global Strobe : 0 - Disable, 1 - Enable
- D4 — Not used

Register Select 2 & 3 - NOT USED

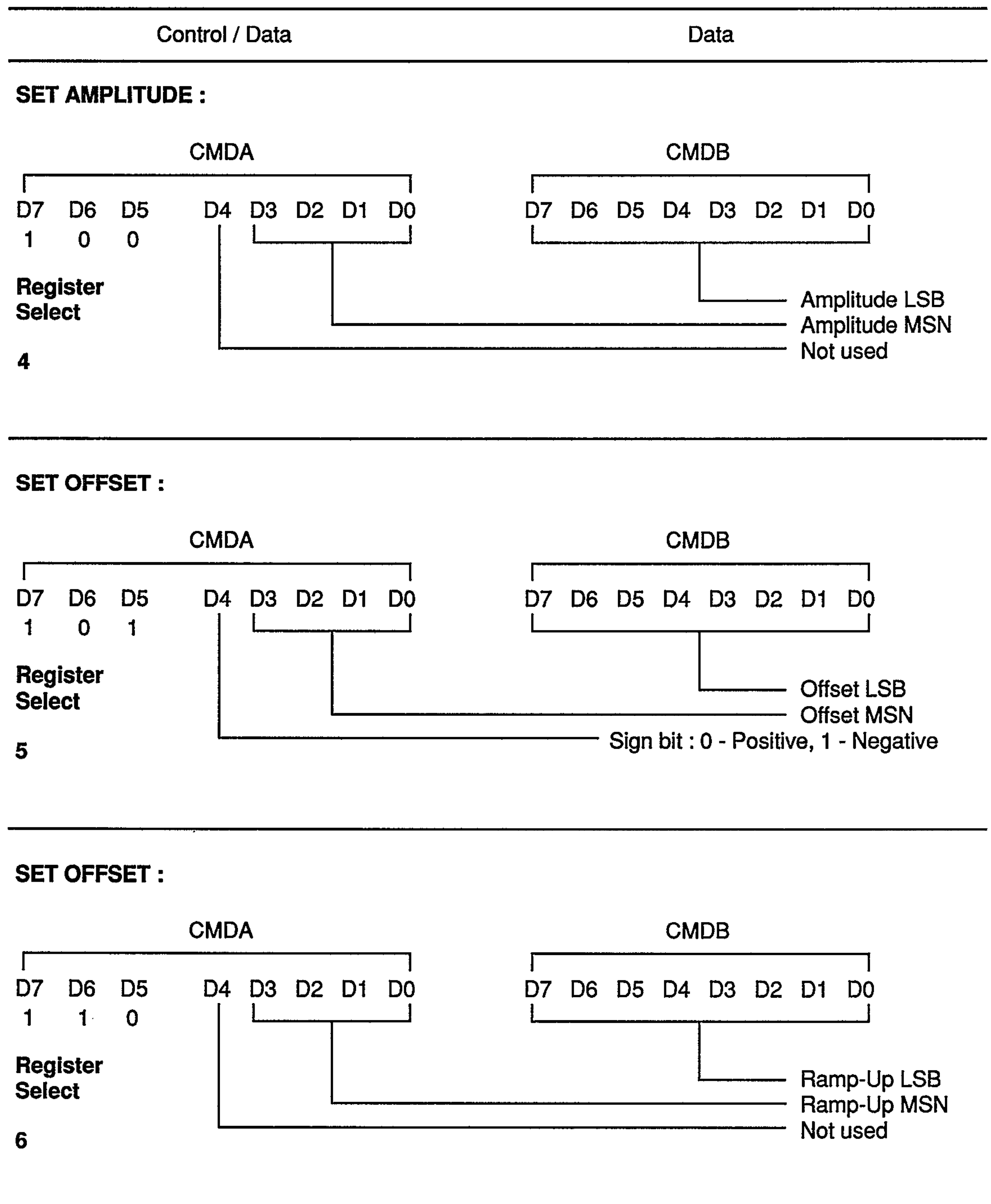
CMDA

D7	D6	D5	D4 D3 D2 D1 D0
0	1	0	Register Select 2 is not used
0	1	1	Register Select 3 is not used

CMDB (not used)

D7 D6 D5 D4 D3 D2 D1 D0

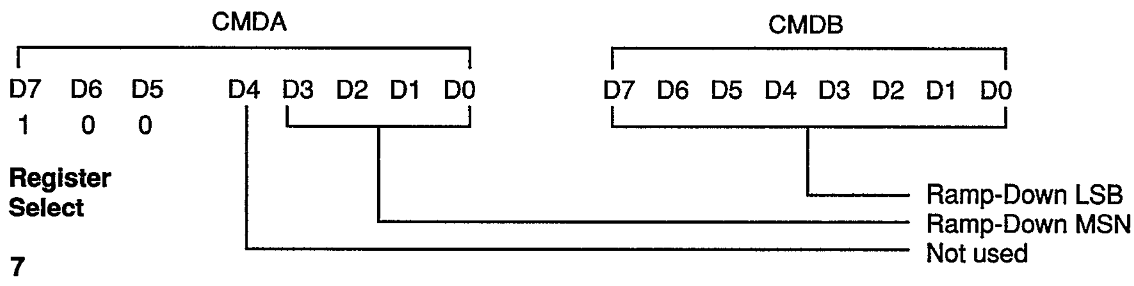
WAV1 Block Diagram and Register Functions (Cont.)



WAV1 Block Diagram and Register Functions (Cont.)

Control / Data	Data

SET RAMP-DOWN :



NOTES :

1. The upper 3 bits of the CMDA register select registers within the WAV1.

2. The DAC's require 12 bits of data, and thus, 2 successive 8-bit writes. The first write must be to CMDA (MSB), and the second to CMDB (LSB). The CMDA write selects the proper DAC register pair to be updated. After the CMDB write, the last register select remains in effect until the next CMDA write operation selects a different register. This allows for faster successive updates of the DAC LSB last written.

3. The MSB contains 3 bits of register select information and 4 bits of actual DAC data (Most Significant Nibble, or MSN). Data bit D4 is used only for polarity selection as part of offset programming. When D4 is not used, it may be assigned a value of 0 or 1 with the same results. The 3 register select bits, bit D4, and DAC MSN data must be combined before writing to CMDA of the WAV1. Frequency, amplitude and DC offset functions are controlled by four 12-bit DAC's.

4. The WAV1 function, range, output enable/disable, synchronized stop enable/disable and global strobe enable are controlled by CMDA-only writes. The subsequent CMDB write will have no effect. CMDA/CMDB reads are not supported by the WAV1.

WAV1 Block Diagram and Register Functions (Cont.)

Using the WAV1

Typically, the WAV1 will be used in conjunction with other modules in a Keithley data acquisition system. Once programmed, the WAV1 will continue to output a waveform with no additional intervention from the computer. The full facilities of the computer can thus be used to control analog and digital I/O. Alternately, the WAV1 can be programmed repetitively within a program to change frequency, amplitude, waveform type, etc. This permits complex waveforms to be generated and reproduced each time the program is run.

To program the WAV1, note the slot in which the module resides, and write to the corresponding CMDA and CMDB registers (see Table 4). A complete configuration of the WAV1 requires 10 writes. For subsequent minor changes such as a new frequency, duty, or amplitude, one or two writes will generally be sufficient.

In each case, the appropriate bit values D0-D7 must be chosen and assembled into byte values which are written to the CMDA and CMDB slot-dependent addresses. The function of each write is further defined by the WAV1 register select bits (bits 7, 6, and 5) written to CMDA.

Before writing any data to the WAV1, set the amplitude switch on the connector-end of the module for 1V or 10V full-scale. The maximum available offset of 1V or 10V is also controlled by this switch, and will be the same as the amplitude.

By using the following sequence of writes, you will be able to set up the WAV1 with the desired operating parameters, and then switch on the output. Depending on the programming language, these operations can be performed in a subroutine or subprogram which can be executed each time a change in the WAV1's output is desired.

1. Select desired frequency (freq), duty cycle (duty), amplitude (amp), offset (offs), and sync stop mode (ss). Assign necessary values for function select, range select, sync stop, and enable bits.

   fs = function select (0 for DC, 1 for sine, 2 for triangle, 3 for square wave.

   freq = desired frequency in Hz (0.1 - 200000).

   rs = range select (0 for 200kHz, 1 for 20kHz, 2 for 2kHz, 3 for 200Hz, 4 for 20Hz, 5 for 2Hz).

   rng = range full-scale in Hz (200000, 20000, 2000, 200, 20, or 2).

   duty = desired duty cycle in percent (5-95).

   amp = desired amplitude in volts (0-10, or 0-1V, depending on setting of the range switch).

   offs = desired offset and polarity in volts (-10 to +10).

   ss = sync stop bit (1 for synchronous waveform stop, or 0 for immediate stop).

   en = output enable. Will normally be set to 1 to enable output when the last write is made to CMDA. 0 disables output.

2. Calculate high byte and low byte for frequency DAC up/down ramps according to selected range, desired frequency, and duty cycle.

```
' Calculate_ramps:

ramp_up = INT((freq * 2^11 - 1) / (rng * (1 - (duty / 100))))

ramp_dn = INT((freq * 2^11 - 1) / (rng * (duty / 100)))

' Test if either ramp > 4095 and recalculate if necessary

IF ramp_up > 4095 OR ramp_dn > 4095 THEN
     rng = rng * 10
     rs% = rs% - 1
     GOTO "calculate_ramps" (beginning of step 2)
     and recalculate...

' Calculate high/low byte values for frequency DACs

ruh = ramp_up \ 256          ' Integer division
rul = ramp_up MOD 256

rdh = ramp_dn \ 256          ' Integer division
rdl = ramp_dn MOD 256
```

3. Calculate high byte and low byte for amplitude DAC.

```
bits = (amplitude / F.S. output) * 4095
ah = bits \ 256
al = bits MOD 256
```

(F.S. output = 1 or 10, depending on range switch position.)

4. Calculate high byte and low byte for offset DAC .

   bits = (abs. value (offs / F.S. offset)) * 4095
   oh = bits \ 256
   ol = bits MOD 256
   op = offset polarity (0 for pos, 1 for neg)

   (F.S. offset = 1 or 10, depending on range switch position.)

5. Do the POKEs

```
' POKE high and low bytes to the ramp-down DACs.
' Register select = 7

POKE cmda, (7 * 32) + rdh
POKE cmdb, rdl

' POKE high and low bytes to the ramp-up DACs
' Register select = 6

POKE cmda, (6 * 32) + ruh
POKE cmdb, rul

' POKE high and low bytes to the offset DACs
' Register select = 5

POKE cmda, (5 * 32) + (op * 16) + oh
POKE cmdb, ol

' POKE high and low bytes to the amplitude DACs
' Register select = 4

POKE cmda, (4 * 32) + ah
POKE cmdb, al

' POKE range and global strobe values
' Register select = 1

POKE cmda, (1 * 32) + gs * 8 + rs

' POKE sync stop, output enable, and function
' Register select = 0

POKE cmda, (0 * 32) + (ss * 8) + (en * 4) + fs
```

The following discussions cover a few of the operating parameters where necessary details are not immediately obvious.

Frequency and Duty Cycle

The frequency and duty cycle are simultaneously controlled by the values loaded into the frequency ramp-up and ramp-down DACs for one cycle. The up and down terminology relates best to the triangle waveform upon which the sine wave can be superimposed. The duty cycle parameter can be understood more easily as the positive portion of a square wave in relation to one complete cycle. See Figure 5 for waveform relationships. For optimum accuracy, select the lowest range which accommodates the desired frequency.

Full-scale for frequency range is obtained by programming both the "up" and "down" DAC's with 4095 (FFF hex). Programming both DACs to the same value will result in a 50% duty cycle. Some typical frequency DAC values for 50% duty cycle are shown in Table 4.

Table 4. DAC Values and Programming Equivalents

% of F.S.	Decimal	Hex	"UP" DAC CMDA	"UP" DAC CMDB	"DN" DAC CMDA	"DN" DAC CMDB
100	4095	&HFFF	&HCF	&HFF	&HEF	&HFF
80	3276	&HCCC	&HCC	&HCC	&HEC	&HCC
60	2457	&H999	&HC9	&H99	&HE9	&H99
40	1638	&H666	&HC6	&H66	&HE6	&H66
20	819	&H333	&HC3	&H33	&HE3	&H33
0	0	&H000	&HC0	&H00	&HE0	&H00

Note: For 50% duty cycle, program "UP" and "DN" DAC's with the same values.

The duty cycle is controlled by the ratio of values written to the frequency up and frequency down DACs. Programming both DACs to the same value will result in a 50% duty cycle since up and down times will be equal.

Note that as a frequency increases toward 100% full-scale, the range of permissible duty cycles narrows toward 50%. The duty cycles available for a given frequency and range can be calculated as follows:

low_duty (%) = 100 * (freq/rng) / 2
high_duty (%) = 100 - low_duty

At some duty cycles and frequencies, the ramp calculations will produce a ramp-up or ramp-down value greater

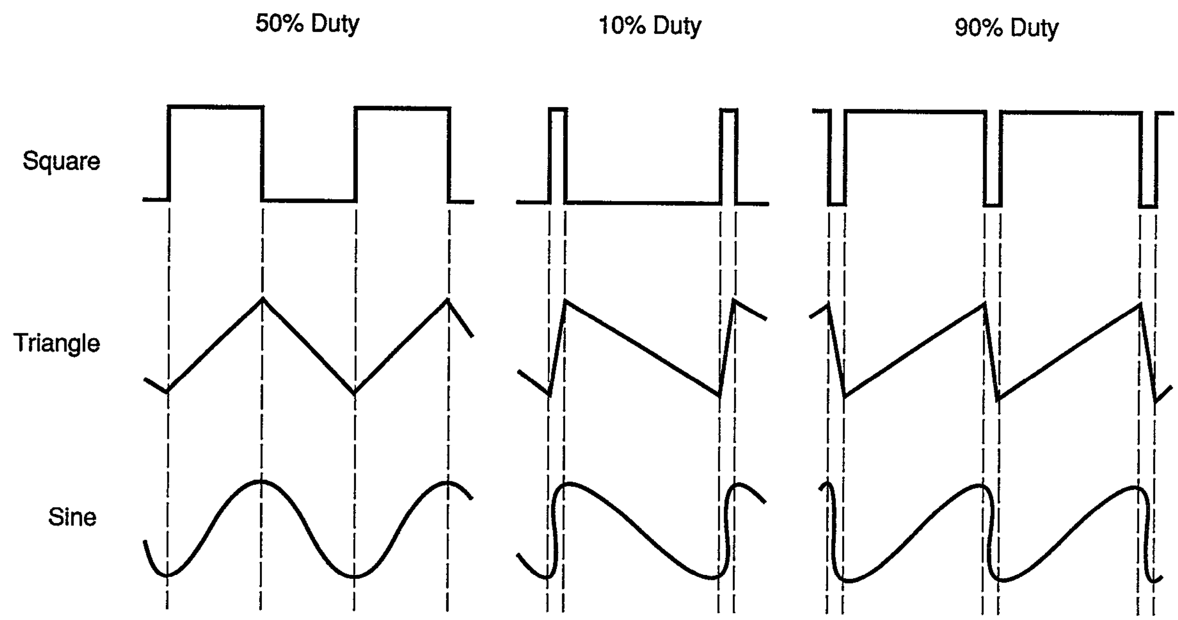


Figure 5. WAV1 Waveform Phase Relationships

than 4095 counts. If so, it will be necessary to select the next higher range and recalculate the DAC values to achieve the desired duty cycle.

Amplitude and Offset

To assure that the WAV1 output remains off and at 0V until fully programmed, the amplitude, offset, and enable bits should be programmed simultaneously, and after all other WAV1 set-up information has been written to the module.

If the amplitude and offset are programmed while the enable bit is set to 0, the WAV1's output will immediately assume the lowest voltage that results for the given amplitude and offset. Thus, there will be some activity at the output even before the waveform commences. When the enable bit is set to 1, the actual waveform will start.

Synchronous Stop Enable/Disable

The synchronous stop bit controls how the WAV1 output waveform terminates. If the synchronous stop bit is set to 0 (disabled), the WAV1 output will turn off immediately when the output enable bit is reset to 0. Note that the output will return to the lowest amplitude point in the waveform, which may or may not be 0V.

If the synchronous stop bit is set to 1 (enabled), the waveform will complete the current cycle before switching off. This means that at lower frequencies, the WAV1 output may continue for several seconds after the output has been disabled. Again, the output will return to the lowest amplitude point in the waveform, which may not be 0V.

The synchronous start/stop feature only applies to sine and triangle waveforms. A square wave will terminate at a voltage level somewhere on the falling edge of the waveform.

Global Strobe Enable/Disable

The global strobe enable/disable bit determines when the WAV1 output will update after new data has been written to the module. This feature permits several WAV1 modules (as well as other analog output modules) to be programmed individually, after which all outputs can be updated simulataneously with one write to the system strobe (address xxx9D).

The WAV1 functions associated with the global strobe are those functions controlled by D/A converters: amplitude, frequency, and offset. If the global strobe feature is enabled, the WAV1 DAC-related functions will not update until a global strobe pulse has been issued by the data acquisition system. If the WAV1 global strobe feature is disabled, any new information will take effect immediately when is written to the WAV1 module.

Haversine Pulse

A haversine is a single sine output pulse, e.g. a pulse with sinusoidal shape which rises from the minimum amplitude point, reaches the maximum amplitude, and decays back to the minimum. WAV1 haver pulses should be programmed for sine and triangle waves. Programming a haver square wave can result in the output pulse terminating at any point along the trailing edge of the pulse, rather than at minimum amplitude.

Haver pulses can be performed by first doing the usual set-up writes to WAV1 registers 7, 6, 5, 4, and 1 as shown above. Next, a write must be made to register 0 to simultaneously set the desired amplitude and turn on the sync stop and output enable bits. This write should be followed immediately by another write to register 0 which turns off the output enable bit. Since the sync stop feature is enabled, one complete pulse should result at the output.

The speeds which can be achieved for haver pulses depend on the speed of the computer and the speed at which the output enable and disable writes can be executed. In this respect, performance improves dramatically under a compiler language. A 10MHz 286 computer executing a compiled (.EXE) file can fire a single haversine pulse at 200kHz.

An oscilloscope can be used to examine the ouput of the WAV1 at higher frequencies. If the speed of the language or computer is insufficient for haver pulses at a given frequency, multiple pulses will be generated and observed on the scope.

Using the WAV1 as a DC Bias Source.

The WAV1 can be used as a DC bias source with up to 20mA of output current capability. The DC output function must be selected, and the desired DC level must be programmed as offset (refer back to programming the offset DAC high and low bytes and polarity). The DC level will appear at the WAV1 output when the output enable bit is turned on. The frequency and amplitude DACs have no effect in this mode of operation, and should be set to 0 when the WAV1 is used for DC output.

Notes:

1. The WAV1 specifications are valid only with an AMM installed in slot 1. If the WAV1 is intended for use in a system that does not contain an AMM, an optional resistor 5K ohm 0.1% (R53, included) must be installed. See the component layout for the location of R53.
2. The WAV1 output signal will contain some spurious noise. Some of the noise is generated by the mainframe into which the WAV1 is installed, some by the WAV1 itself.
   a. The WAV1 generated noise will be at a maximum with the output amplitude set to a minimum (<1% of F.S.), and the square wave function or synchronous stop functions selected. This noise is caused by capacitive coupling through the amplitude attenuator DAC. Since it is capacitively coupled, the noise will be more pronounced at higher programmed frequencies. Selecting sine, triangle or DC waveforms will reduce the noise.
   b. System-induced noise may be reduced by using a shielded BNC cable from the WAV1. Any unshielded wires connected to the WAV1 can also couple additional noise onto the output.
   c. A low-pass filter may be added to the input of the driven device to further reduce the amplitude of any noise present.

Calibration

This section contains general field calibration information for the WAV1. The procedures given are not necessarily as accurate as factory calibration. Also, the procedures given assume a certain amount of expertise on the part of the user. If you are not familiar with calibrating equipment, do not attempt calibration. The procedures in this section assume that you are familiar with general module operation. Refer to the appropriate manual for details on calibrating each module.

The WAV1 has four calibration adjustments; ramp-up zero, ramp-up gain, ramp-down zero and ramp-down gain. The adjustments are somewhat interactive and therefore must be performed in the proper order for calibration to be achieved.

The ramp zero and gain interact with one another in addition to the ramp-up zero and gain affecting the ramp-down zero and/or gain. The ramp-down adjustments do not, however, affect the ramp up adjustments.

Required equipment:

4-1/2 digit DVM, accuracy better than 0.1%.
Frequency Counter with pulse period capability.

Environment: 23°C ±5°C, less than 35% R.H., non-condensing

NOTE
The WAV1 specifications are valid only with a calibrated AMM installed in slot 1 providing a VREF of +10 volts to the WAV1.

Procedure (refer to the component layout Figure 1 for location of test points and calibration controls).

1. Adjust ramp zero voltage for 0V ±5mV on TP4 and TP5 using RP1 and RP2.
2. Program the WAV1 to output a 500Hz square wave, full scale amplitude, zero DC bias.
3. Connect the frequency counter to the BNC output and set to measure pulse low width. The square wave is low during the ramp-up portion of the sine and triangle waveforms.
4. Adjust ramp-up zero (RP1) for 1.00ms ±.02ms reading on the frequency counter.
5. Program the WAV1 to output a 2000Hz square wave.
6. Adjust ramp-up gain (RP3) for 250µs ±5µs.
7. Repeat steps 2 through 6 until the readings remain within specified limits.
8. Program the WAV1 to output a 500Hz square wave, full scale amplitude, zero DC bias.
9. Set counter to measure pulse high width.
10. Adjust ramp-down zero (RP2) for 1.00ms ±.02ms reading on the frequency counter.
11. Program the WAV1 to output a 2000Hz square wave.
12. Adjust ramp-down gain (RP4) for 250µs ±5µs.
13. Repeat steps 8 through 12 until the reading remains within specified limits.
14. Verify all four calibration points remain within specifications. Repeat entire procedure if necessary to obtain convergence.

Performance Verification

Required equipment:

4-1/2 digit DVM, accuracy better than 0.1%
Oscilloscope with 20MHz bandwidth.
1MHz frequency counter.
AMM1A or AMM2 in slot 1 supplying reference

Procedure (Global strobe disabled for all tests, 10V range)

1. Program the WAV1 for DC function, output disabled, 200KHz range, 0Hz frequency, 0V amplitude and 0V offset. Set the range DC function switch to 10V position.
2. Connect DVM and Scope (counter optionally) to main output.
3. Observe DVM, reading should be less than ±10mV.
4. Observe scope, output should be DC with no significant oscillations present.
5. Program +1V offset.
6. Observe DVM, reading should be 1V ±15mV.
7. Program -1V offset.
8. Observe DVM, reading should be -1V ±15mV.
9. Repeat steps 5 through 8 for programmed and observed values of ±2, ±5, ±10V. Substitute appropriate errors based on amplitude.
10. Program the WAV1 for Triangle function, output enabled, 200KHz range, 200KHz frequency, 1V amplitude and 0V offset.
11. Observe scope, output should be a 1V peak, 200 KHz triangle wave. Use the counter to determine whether the output is within specified limits.
12. Repeat steps 10 and 11 for all full scale frequencies on the five remaining ranges.
13. Repeat steps 10 through 12 for 2V, 5V and 10V amplitudes.
14. Repeat steps 10 through 12 for sine and square wave functions. Random sampling of 10% and 50% of full scale frequencies and amplitudes can be performed to the testers satisfaction.
15. Program the output for DC function, 1V offset.
16. Set range switch to 1V range position.
17. Observe DVM reading .1V ±11mV.

Theory of Operation

WAV1 operation involves analog as well as digital circuitry.

Analog

The WAV1 is based on a function generator IC, the ICL8038. The IC provides the following facilities necessary for the operation of the WAV1:

2 switchable current sources
2 comparators for control of current sources
Triangle wave to sine wave conversion
Square wave output

The current sources are varied to control the magnitudes of their charge and discharge currents. The ramp-up and ramp-down times, and thus the frequency and duty cycle, are varied in this way. The ratio of the values of the two current sources determine the output duty cycle. The current sources are controlled by dual D/A converter U12. These are two 12-bit DAC's with their reference inputs supplied by U19, the 8038. This reference is buffered by U18B and level shifted referenced to analog ground by differential amplifier U18A. The reference voltage is essentially divided by the value programmed into each of the two DAC's to produce an output current which is subsequently converted back into a voltage by amplifiers U16A and U16B. The scaled DAC output voltages are fed to differential amplifiers U17A and U17B which level shift, relative to the 8038's reference output, and feed the current source control inputs of the 8038.

The 8038 switches the appropriate current source onto the timing capacitor connected to pin 10. The value of the capacitor determines the range of available frequencies. The available values of range capacitors are ~1000pF to 100µF. These values correspond to frequency ranges from 200KHz to 2Hz respectively. The group of analog switches comprised of transistors Q3 through Q16 switch the selected capacitor onto 8038 pin 10.

The three outputs of the ICL8038 are normalized to 3.333 volts peak, buffered and fed to a four line multiplex switch comprised of U21 and U22B. The triangle output, essentially the capacitor voltage, is impedance buffered by amplifier U20B. The sine wave output, having a slightly reduced amplitude compared to the triangle wave, is buffered and amplified slightly by U20A. The square wave output is buffered by a complimentary MOSFET amplifier composed of transistors Q21 through Q23. A resistor divider composed of R37 through R40 scales the square wave to 3.333 volts peak.

The mux output is buffered by U24B and fed to DAC U13A. The output of U13A and I-V conversion amplifier U24A is proportional to the digital code programmed into U13A given a 3.333V peak input. The main signal is fed to the WAV1's output amplifier U26, which has a gain of 3 or .3 depending on range switch setting, resulting in a maximum output of 10V or 1V peak respectively. DAC U13B, reference selector switch U15A, buffer U25B, and I-V amplifier U25A provide a 10 volt bipolar signal which is summed into the main signal path with an effective gain of 1 or 0.1, depending on range switch setting, thus biasing the output signal on a DC voltage of 10V or 1V respectively.

U9, U10 and associated circuitry provide plus and minus 10 volt reference supplies. The output transistors Q1 and Q2 provide additional current driving capability.

U11 and associated circuitry provide a low-true reset pulse on power-up and down transitions.

U23A one-shot provides a 500ns low-true pulse on every negative transition of the main square wave output. This signal is fed exclusively to the system baseboard daisy chain bus in the direction of slot 1 (AMM). U23B one-shot provides 1µs complimentary pulses to the user connector J2. The PC board is designed to accept a potentiometer and resistor to allow the user to vary the output pulse width.

Digital

Logic gates U1, U2 and U3 decode the baseboard control signals for interfacing with the DAC's, function and range select registers. U4 is a transparent latch that holds the three most significant data bits last selected by a CMDA write. U5 decodes chip selects from the 3 MSB's and feeds them to U6, range register, U7 function register and U8B offset polarity register. Register U7 contains output enable/disable and synchronous stop enable/disable bits in addition to function select bits. The remainder of the decoding is done by the DAC internal gating circuitry.

Troubleshooting

Any observed or suspected problem with a system or module may be the result of malfunctions in any part of the system. A hierarchy of possible problem areas is listed below. The list should help you apply an organized approach to troubleshooting, starting with software and working toward a specific module. It assumes that your system and software have both worked properly in the past. If you have spares, you can most quickly verify a system component through simple substitution. Check your data acquisition system manual or computer documentation — they may contain additional instructions on troubleshooting.

1. Faulty software or applications programs - If you have completed a new program which does not work as anticipated, review the program design and be certain that it actually functions as you assume. If a program which had been running properly begins to behave erratically, either the supporting software package or the application program may have been corrupted. This may occur through disk media failures, power supply problems, hardware failures, or operator error.

   Verify your software package against a back-up copy or the original diskettes. If the software is questionable, you should reinstall the software from the original diskettes or known-good copies. Likewise, your applications program should be restored from backups if a problem develops. Note that it is crucial to back up important software and programs. Ideally, you should make at least two copies, and store one in a location away from your work site. Application programs should be backed up regularly as they are being developed. Printouts of program listings may also be desirable.
2. Faulty computer system - A malfunctioning computer or peripheral can affect the data acquisition software and hardware, ranging from minor problems to total failure. These problems may be continuous or intermittent. If you suspect your computer, remove the data acquisition interface and run any diagnostics which came with the system to verify its performance. Also try running other software with which you are familiar. Pay close attention for any erratic behavior of the software which may indicate hardware problems.
3. Defective interface - A malfunctioning data acquisition interface can prevent the computer from booting up and operating properly, or it can affect only the data acquisition system. Some graphics, mouse, and networking adapters conflict with data acquisition interfaces as a result of both using the same addresses or interrupts. The system operates properly with one of the cards in place, but diagnostic error messages or other problems result with both cards plugged in. You can usually determine incompatibility by trying each suspected card individually, and then together. Such incompatibility can often be overcome through switch settings, configuration changes, or minor modifications to the hardware.
4. Defective data acquisition interface cable - The cable carries essential power, control, or data signals. Open conductors in a cable will disrupt the process. Cable shorts, especially in lines carrying system power supply voltages, may cause a total shutdown of the computer or data acquisition mainframe. If these problems exist, try disconnecting the interface cable from the computer and data acquisition system.

   There is a maximum permissible length specified for interface cables. Exceeding the length will also introduce problems. You may note erratic operation of the computer, corrupt data, or a failure of the indicator lamps on the data acquisition system to light.
5. Defective data acquisition mainframe - A mainframe defect can affect any and all data acquisition functions. Main areas include the mother board logic and connectors, the expansion slots, and the power supply. In the case of a completely dead acquisition system, always check any fuses and cabling which carry power.

   An individual slot may also be bad. A known good module can be tried in various slots to determine the condition of individual mainframe slots.
6. Defective module(s) in general - A failure in a module's address, data, or control circuitry can affect other modules if the malfuctions ultimately reach the data acquisition mother board or power supply. You may be able to locate a faulty module by removing modules individually until the problem clears.

   The master A/D module in slot 1 is a special case because it processes data from all analog input channels. Any analog input involves its global multiplexer, programmable gain amplifier, and A/D converter. If only the analog input functions are faulty, you should also consider the master A/D module. Use a known-good A/D module, or first verify your A/D module for proper operation before troubleshooting another analog module.

   Analog output normally relies only on circuitry within an analog output module unless documentation for the module states otherwise. The AOM5 modules uses the 10V precision reference on the AMM module. If you note inaccurate output levels from the AOM5, the AMM module may need to be calibrated.

Digital input and output are also performed wholly on a single module, with the exception of the PIM1 and PIM2 power control modules. The PIM modules use an external board and solid state relays. These should also be considered in situations where PIM modules are suspected of being faulty.

In troubleshooting modules, use a software package with which you are familiar to write a few simple test programs for the suspected module. Elaborate programs should generally not be used. They may contain their own errors which mask problems with the hardware.

If a suspected module does not respond as expected, you may assume that the module requires calibration or is defective. If a module has no calibratable components, a problem at this point will normally indicate a failure within the module.

7. Defective WAV1 module - A WAV1 can be checked by running a few simple programs which test individual features of the module. The CMDA and CMDB registers can also be exercised to determine correct operation of the module. See information elsewhere in this manual.

A skilled technician who has access to electronic test equipment may be able to troubleshoot individual circuits on a module to isolate the faulty parts. A full parts list and diagram set are included with each module to aid the technician.

If a defective component is found, replacement parts may be obtained from Keithley. If factory service is desired, the module may be returned for repair. All Keithley-manufactured systems and modules are warranted against defects in material and workmanship for a period of one year. For information on replacement parts or factory service, see the Parts List section of the appropriate manual.

NOTE

The basic accuracy of the WAV1 module is 5%. If a WAV which had been working properly suddenly becomes inaccurate by more than a few percent beyond nominal, the problem is more likely a malfunction and not a calibration problem. If you cannot calibrate the hardware after two attempts, you should return it to Keithley for repair or calibration at the factory.

List of Replaceable Parts

This section contains replacement parts information, component location drawings and schematic diagrams. Parts are listed alphanumerically in order of their circuit designations.

Ordering Information

To place an order, or obtain information concerning replacement parts, first contact the Keithley customer service department at (216) 248-0400. When ordering parts, include the following information:

1. Model Number
2. Serial Number
3. Part Description
4. Circuit Designation (if applicable)
5. Keithley Part Number

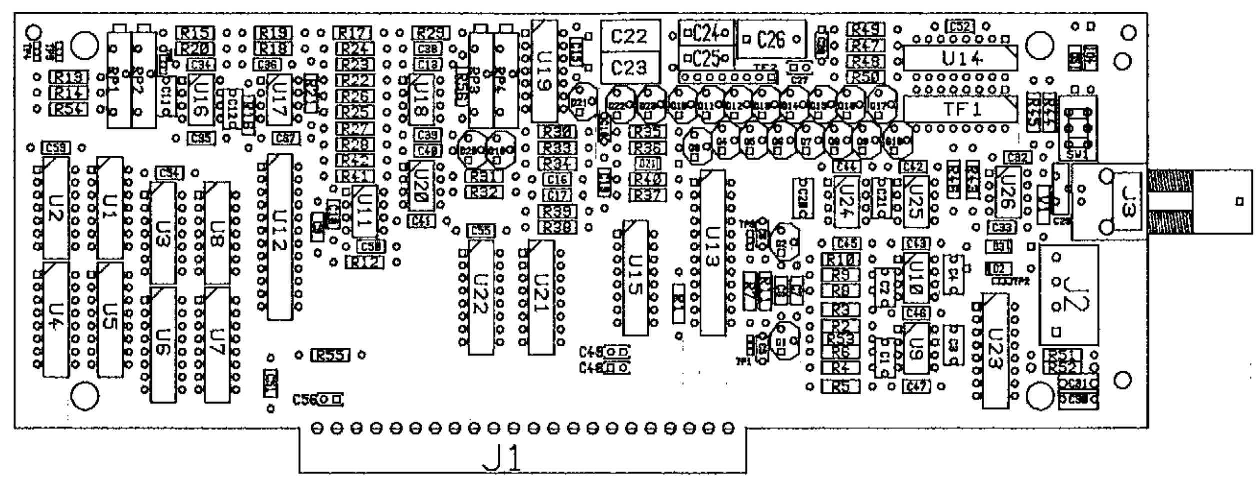
If an additional instruction manual is required, order the manual package (Keithley Part Number 501-921-00). The manual package contains an instruction manual and any applicable addenda.

Table 5. Parts List - Model WAV1 Analog Output Module

Part No.	Quantity	Title	Designation
C-138-680P	1	Cap, 680pF, 5%, 500V, polystyrene	C22
C-138-68P	1	Cap, 68pF, 5%, 500V, polystyrene	C23
C-179-10	3	Cap, 10µF, 20%, 20V, tantalum	C48, C49, C56
C-204-1	1	Cap, 1µF, 10%, 20V, tantalum electrolyte	C26
C-204-10	1	Cap, 10µF, 10%, 20V, tantalum electrolyte	C27
C-22-.0022	2	Cap, .0022µF, 20%, 500V, ceramic	C1, C2
C-228-100	1	Cap, 100µF, 10%, 15V, tantalum	C28
C-237-1	3	Cap, 1µF, 20%, 50V, ceramic	C5, C6, C18
C-306-.01	1	Cap, .01µF, 10%, 100V, polypropylene	C24
C-306-.1	1	Cap, .1µF, 10%, 100V, polypropylene	C25
C-365-.01	2	Cap, .01µF, 20%, 50V, ceramic	C8, C16
C-365-.1	29	Cap, .1µF, 20%, 50V, ceramic	C7, C9, C10, C13, C15, C17, C19, C32..C45, C46, C47, C50..C55
C-386-270P	1	Cap, 270pF, 20%, 100V, ceramic/ferrite	C29
C-64-100P	4	Cap, 100pF, 10%, 1000V, ceramic	C3, C4, C30, C31
C-64-22P	3	Cap, 22pF, 10%, 1000V, ceramic	C11, C12, C21
C-64-27P	1	Cap, 27pF, 10%, 1000V, ceramic	C20
CS-521-3	1	Conn, strip, 4 pin QD	J2
CS-547	1	Conn, BNC right angle, plastic body	J3
CS-553	6	Conn, test point	TP1..TP6
DZ-75	1	Diode, zener 15V, 1N4744A (TO-41)	DZ1
IC-144	1	IC, dual D-type flip flop, 74LS74	U8
IC-157	2	IC, quad D flip flop, 74LS175	U6, U7
IC-163	1	IC, quad 2 input NAND, 74LS00	U2
IC-179	1	IC, quad 2 input NOR, 74LS02	U1
IC-182	1	IC, decoder/demux, 74LS138	U5
IC-203	2	IC, 18V op-amp, 308AW	U9, U10
IC-320	1	IC, spst cmos analog switch, DG211	U21
IC-366	1	IC, 4 bit bistable latch, 74LS75	U4
IC-398	1	IC, 3-8 line decoder/demulti, 74HCT138	U14
IC-504	6	IC, dual JFET op-amp, 412	U16..U18, U20, U24, U25
IC-510	1	IC, quad 2-input NOR gate, 74HCT02	U3
IC-558	1	IC, dual one-shot, 74LS221	U23
IC-602	1	IC, supply voltage supervisor, TI7705AC	U11
IC-678	2	IC, dual loading 12 bit DAC, AD7537JN	U12, U13
IC-686	1	IC, DPDT analog switch, DG423DJ	U15
IC-720	1	IC, instrumentation amp, AD845JN	U26
IC-721	1	IC, waveform generator/VCO, ICL8038CCPD	U19
IC-722	1	IC, dual 2 to 4 decoder, 74HCT139	U22
J-3	1	Jumper, circuit	W1
R-176-1.15K	2	Res, 1.15k, .1%, 1/8W, metal film	R19, R24
R-176-10K	12	Res, 10k, .1%, 1/8W, metal film	R2..R5, R8, R9, R16, R18, R22, R26, R28, R48
R-176-13.3K	1	Res, 13.3k, .1%, 1/8W, metal film	R1
R-263-1.5K	1	Res, 1.5k, .1%, 1/10W, metal film	R44

R-263-11K	1	Res, 11k, .1%, 1/10W, metal film	R29
R-263-15K	2	Res, 15k, .1%, 1/10W, metal film	R45, R46
R-263-1K	1	Res, 1k, .1%, 1/10W, metal film	R39
R-263-20K	7	Res, 20k, .1%, 1/10W, metal film	R15, R17, R20, R25, R27, R47, R54
R-263-38.6K	1	Res, 38.6k, .1%, 1/10W, metal film	R56
R-263-3K	1	Res, 3k, .1%, 1/10W, metal film	R38
R-263-4K	2	Res, 4k, .1%, 1/10W, metal film	R37, R40
R-263-5.025K	1	Res, 5.025k, .1%, 1/10W, metal film	R42
R-263-5K	4	Res, 5k, .1%, 1/10W, metal film	R21, R23, R43, R53
R-263-9.76K	1	Res, 9.76k, .1%, 1/10W, metal film	R41
R-76-100	3	Res, 100, 5%, 1/4W, composition or film	R6, R10, R34
R-76-10K	3	Res, 10k, 5%, 1/4W, composition or film	R7, R11, R31
R-76-15K	1	Res, 15k, 5%, 1/4W, composition or film	R52
R-76-1K	1	Res, 1k, 5%, 1/4W, composition or film	R33
R-76-22	2	Res, 22, 5%, 1/4W, composition or film	R35, R36
R-76-2K	1	Res, 2k, 5%, 1/4W, composition or film	R49
R-76-4.7K	3	Res, 4.7k, 5%, 1/4W, composition or film	R12, R32, R55
R-76-5.1K	1	Res, 5.1k, 5%, 1/4W, composition or film	R50
R-76-6.8K	1	Res, 6.8k, 5%, 1/4W, composition or film	R51
R-76-82K	1	Res, 82k, 5%, 1/4W, composition or film	R30
R-88-200K	2	Res, 200k, 1%, 1/8W, metal film	R13, R14
RF-28	4	Diode, silicon, 1N4148 (DO-35)	D2, D3, D4, D5
RP-89-1K	2	Pot, 1k, 10%, .75W, non-wirewound	RP3, RP4
RP-89-20K	2	Pot, 20k, 10%, .75W, non-wirewound	RP1, RP2
SW-445	1	Switch (DPDT)	SW1
TF-177-1	1	Res net, 1k, 2%, 2.25W	TF1
TF-179-1	1	Res net, 10k, 2%, 1.3W	TF2
TG-192	1	Trans, N-channel DMOSFET, VN0104NS(TO-92)	Q23
TG-193	1	Trans, P-channel DMOSFET, VPO104N3(TO-92)	Q22
TG-195	7	Trans, N chan MOSPOW FET, 2N7000 (TO-92)	Q10..Q16
TG-47	3	Trans, NPN silicon, 2N3904 (TO-92)	Q2, Q17, Q19
TG-84	11	Trans, PNP silicon, 2N3906 (TO-92)	Q1, Q3..Q9, Q18, Q20, Q21
501-921-00A	1	Manual package	

LTR	ECO NO.	REVISION	ENG.	DATE
A	13974E	RELEASED	SAS	3-9-90
B	14030	MOVED C1-C4,C11,C12,C20,D2 DELETED C14 ADDED R54-R56 CHANGED LEAD SPAN C48,C49,C56 PADS ON J3 MOUNTING PINS	SAS	4-16-90



NOTES:
1) FOR COMPONENT INFORMATION, REFER TO BILL OF MATERIALS 500-WAV1-000.
2) THE FOLLOWING COMPONENTS ARE TO BE USER INSTALLED:
   R53
3) R52 AND C31 ARE TO BE INSTALLED IN PIN SOCKETS (SO-83-1, 4 PCS)

MODEL	NEXT ASSEMBLY	QTY
500	500-WAV1	

USED ON

DO NOT SCALE THIS DRAWING

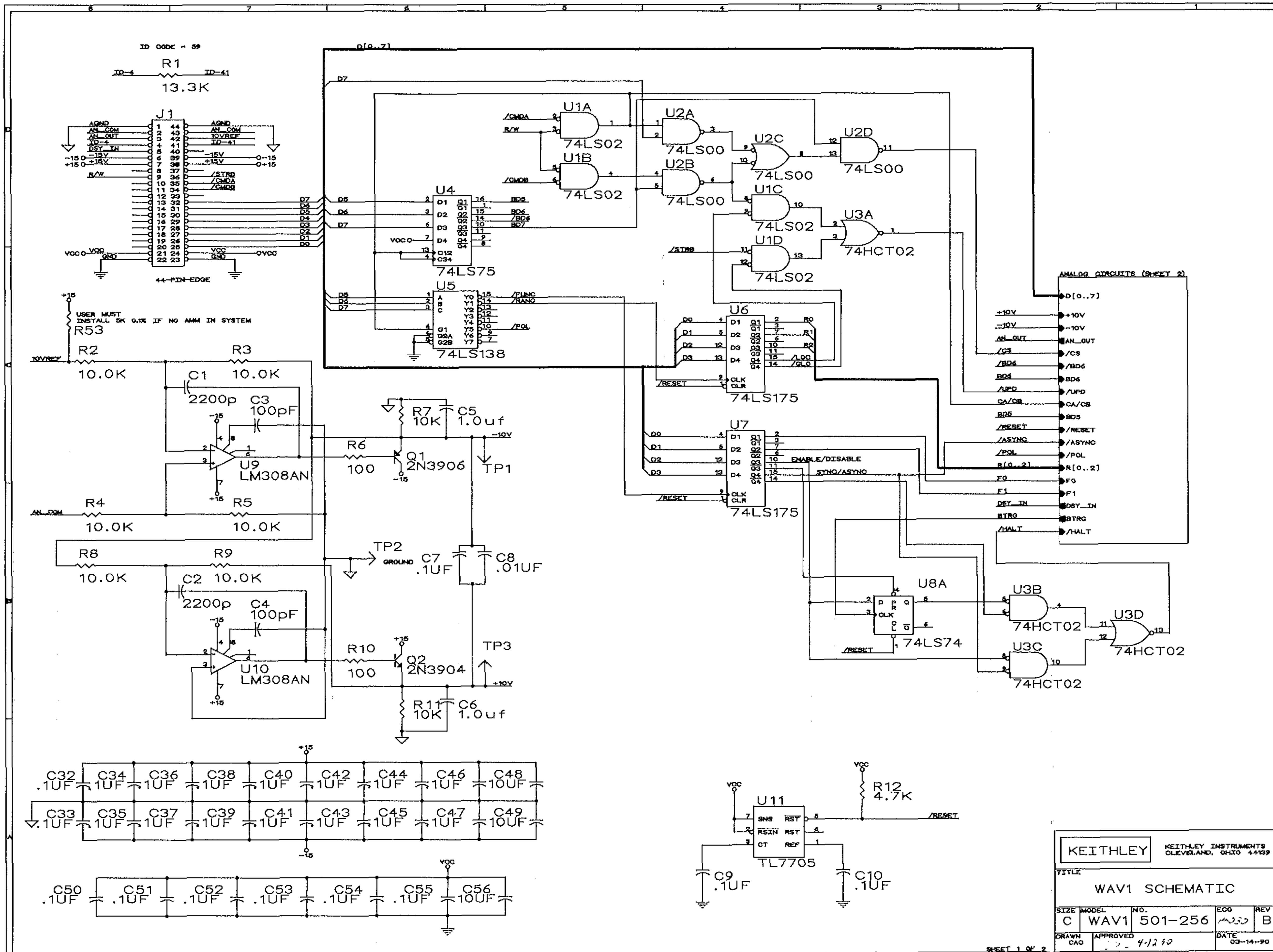
KEITHLEY Keithley Instruments Inc. Cleveland, Ohio 44139

DIMENSION TOLERANCES UNLESS OTHERWISE SPECIFIED
XX=+/-.015 ANG.=+/-1°
XXX=+/-.005 FRAC.=+/-1/64
SURFACE MAX. 63

DATE 3-8-90 SCALE 1:1
DRN. SAS ENG. APPR.
MATERIAL N/A
FINISH N/A

TITLE COMPONENT LAYOUT, WAVEFORM GENERATOR

C NO. 501-250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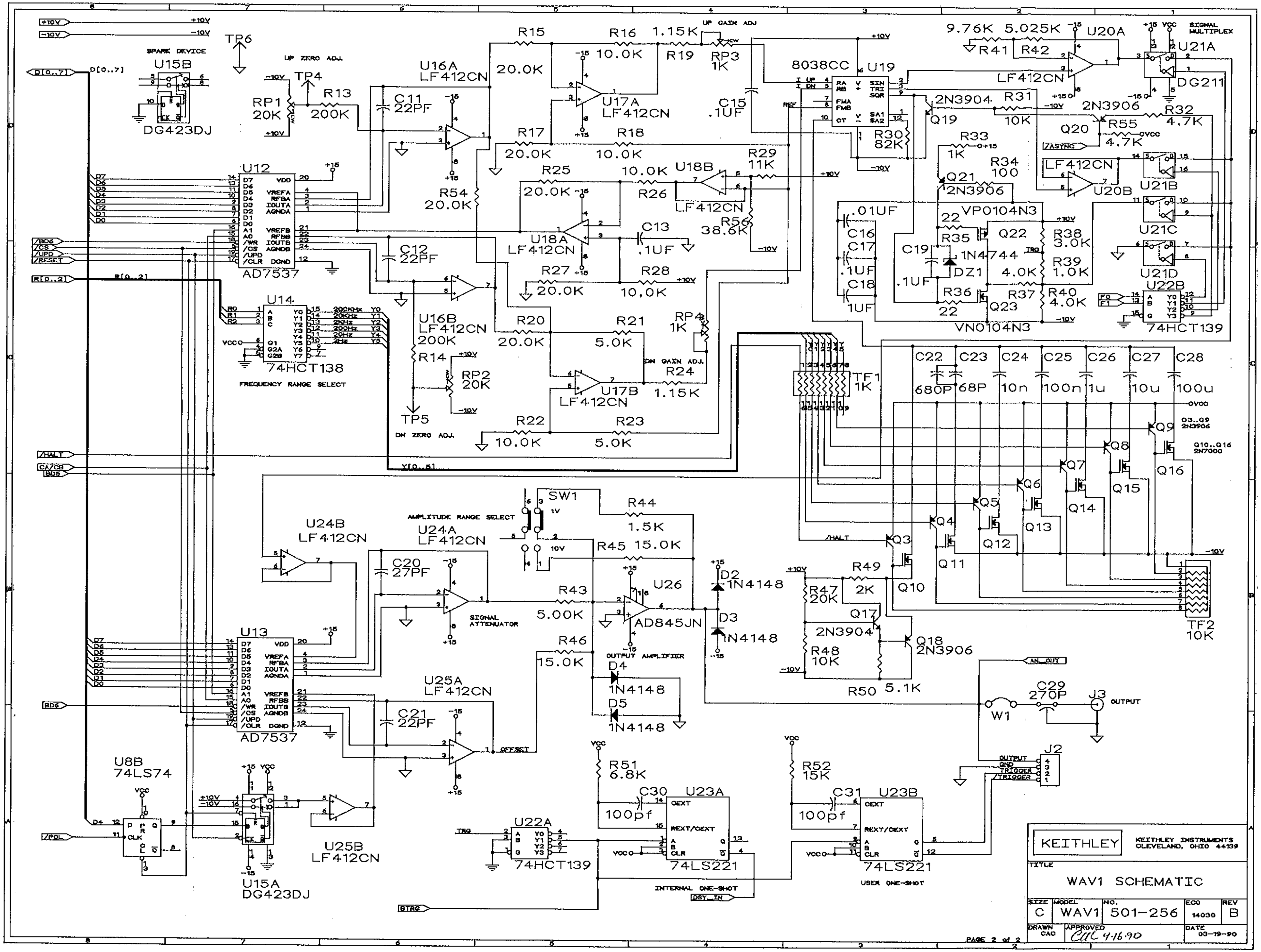
R1 13.3K
J1
44-PIN-EDGE
AGND
AN_COM
AN_OUT
10VREF
DSY_IN
-15V
+15V
R/W
/STRB
/CMDA
/CMDB
VCC
GND
D[0..7]
U1A 74LS02
U1B 74LS02
U1C 74LS02
U1D 74LS02
U2A 74LS00
U2B 74LS00
U2C 74LS00
U2D 74LS00
U3A 74HCT02
U3B 74HCT02
U3C 74HCT02
U3D 74HCT02
U4 74LS75
U5 74LS138
U6 74LS175
U7 74LS175
U8A 74LS74
U9 LM308AN
U10 LM308AN
U11 TL7705
/FUNC
/RANG
/POL
/RESET
ENABLE/DISABLE
SYNC/ASYNC
ANALOG CIRCUITS (SHEET 2)
USER MUST INSTALL 5K 0.1% IF NO AMM IN SYSTEM
R53
R2 10.0K
R3 10.0K
R4 10.0K
R5 10.0K
R8 10.0K
R9 10.0K
C1 2200p
C2 2200p
C3 100pF
C4 100pF
R6 100
R10 100
Q1 2N3906
Q2 2N3904
R7 10K
R11 10K
C5 1.0uf
C6 1.0uf
C7 .1UF
C8 .01UF
TP1
TP2
TP3
GROUND
R12 4.7K
C9 .1UF
C10 .1UF
C32–C47 .1UF
C48 10UF
C49 10UF
C50–C55 .1UF
C56 10UF
KEITHLEY
KEITHLEY INSTRUMENTS CLEVELAND, OHIO 44139
TITLE WAV1 SCHEMATIC
SIZE C
MODEL WAV1
NO. 501-256
REV B
DRAWN CAO
DATE 03-14-90
SHEET 1 OF 2


KEITHLEY
KEITHLEY INSTRUMENTS CLEVELAND, OHIO 44139
TITLE
WAV1 SCHEMATIC
SIZE C
MODEL WAV1
NO. 501-256
ECO 14030
REV B
DRAWN CAD
APPROVED
DATE 03-19-90
PAGE 2 of 2
SPARE DEVICE
U15B
DG423DJ
TP6
UP ZERO ADJ.
TP4
RP1 20K
R13 200K
C11 22PF
U16A LF412CN
R15 20.0K
R16 10.0K
R19 1.15K
UP GAIN ADJ
RP3 1K
U17A LF412CN
C15 .1UF
8038CC
U19
R41 9.76K
R42 5.025K
U20A LF412CN
U21A DG211
SIGNAL MULTIPLEX
R17 20.0K
R18 10.0K
R54 20.0K
U12 AD7537
R25 20.0K
R26 10.0K
U18A LF412CN
U18B LF412CN
R29 11K
R56 38.6K
C13 .1UF
R27 20.0K
R28 10.0K
C12 22PF
U16B LF412CN
R14 200K
RP2 20K
TP5
DN ZERO ADJ.
U14 74HCT138
FREQUENCY RANGE SELECT
200KHz 20KHz 2KHz 200Hz 20Hz 2Hz
R20 20.0K
R21 5.0K
RP4 1K
DN GAIN ADJ.
R24 1.15K
U17B LF412CN
R22 10.0K
R23 5.0K
Q19 2N3904
R31 10K
R30 82K
Q20 2N3906
R55 4.7K
R32 4.7K
R33 1K
R34 100
Q21 2N3906
U20B LF412CN
U21B
U21C
U21D
U22B 74HCT139
C16 .01UF
C17 .1UF
C18 1UF
C19 .1UF
R35 22
R36 22
DZ1 1N4744
Q22 VP0104N3
Q23 VN0104N3
R37 4.0K
R38 3.0K
R39 1.0K
R40 4.0K
TF1 1K
C22 680P
C23 68P
C24 10n
C25 100n
C26 1u
C27 10u
C28 100u
Q3..Q9 2N3906
Q10..Q16 2N7000
TF2 10K
U24B LF412CN
AMPLITUDE RANGE SELECT
SW1
U24A LF412CN
C20 27PF
SIGNAL ATTENUATOR
R43 5.00K
R44 1.5K
R45 15.0K
U26 AD845JN
OUTPUT AMPLIFIER
D2 1N4148
D3 1N4148
D4 1N4148
D5 1N4148
R46 15.0K
U13 AD7537
U25A LF412CN
C21 22PF
OFFSET
R47 20K
R49 2K
Q17 2N3904
Q18 2N3906
R48 10K
R50 5.1K
AN_OUT
W1
C29 270P
J3 OUTPUT
J2
OUTPUT GND TRIGGER TRIGGER
U8B 74LS74
U15A DG423DJ
U25B LF412CN
U22A 74HCT139
R51 6.8K
C30 100pf
U23A 74LS221
INTERNAL ONE-SHOT
R52 15K
C31 100pf
U23B 74LS221
USER ONE-SHOT
D[0..7]
R[0..2]
Y[0..5]
/BDS
/CS
/UPD
/RESET
/HALT
CA/CB
BDS
/POL
BTRG
DSY_IN
/ASYNC
+10V
-10V

Writing a Custom Driver for the WAV1 Module

The WAV1 module is a programmable source of sine, square and triangle waves at frequencies of 0.1 to 200kHz and duty cycles of 5% to 95%. A DC offset function permits the module to be used as a DC bias source, or to offset the output waveforms relative to 0 volts.

The WAV1 can operating autonomously once it has been programmed, leaving more processor time for performing acquisition, output, or data management tasks. Since the module is software-controlled, any special waveforms, modulations, etc. can be reproduced each time the program is executed.

Programming the WAV1 is somewhat more involved than other 500-series modules because the WAV1 has a greater number of operating parameters. A complete WAV1 set-up requires 10 writes, whereas most other I/O modules need only a few reads and/or writes. Once the basic WAV1 configuration has been set, however, a single parameter such as frequency, amplitude, or duty cycle can be modified independently. In this regard, the WAV1 is easier to program than most other modules.

A WAV1 can be controlled completely through BASIC POKE statements or similar memory-write functions of other languages. While this may seem more difficult than using a high-level command, any high-level command still needs to address all the WAV1's parameters. Further, controlling the WAV1 at a primitive level offers the following advantages:

- The WAV1 can be operated from any programming language, regardless of whether the language offers specific support for the WAV1. Soft500, Quick500, and earlier KDAC500 versions do not support the WAV1. Users of these packages might want to add the WAV1 to their systems.
- The user will have maximum control over the WAV1. Any pre-written driver for the WAV1 may make certain assumptions or compromises. The WAV1's extensive set of configuration parameters provides many possible methods of operating the module. Accessing the WAV1 directly at the hardware level gives the programmer ultimate real-time control over the module.

KEITHLEY DAC

- Communication with the WAV1 can be totally customized to the application. The program may include prompts, status messages, and error checking as needed.

A QuickBASIC Driver for the WAV1

The end of this note provides a listing for a WAV1 driver written in QuickBASIC V4.5. This is an example of a general-purpose driver which can access all the WAV1's capabilities. It can be used as a sub-program, or compiled and combined with QuickBASIC's libraries. The listing can also be used as a guide to writing a driver in some other language. The source code can be reduced by about one fourth if the comments are omitted.

A few comments are in order concerning the driver. First, when used as a sub-program the driver must be declared "SUB" in the beginning of the main QuickBASIC program. This is accomplished with the following statement:

DECLARE SUB wav1 (addr&, sl%, command.string$)

This form was chosen to simplify programming the module. The command syntax includes a parameter list which passes the system interface address, the WAV1 slot, and a string of operating commands to the WAV1. The inclusion of address and slot supports using several WAV1s or mainframes on one computer.

The WAV1 driver command string is a string consisting of all, or only one of, the sub-commands. The complete string may be a literal variable, or can consist of the actual sub-commands enclosed by quotes. Each sub-command consists of the parameter type (wave, amplitude, duty, etc.), followed by an equal sign and the desired value. Only the first three letters need to be used for the type. Multiple sub-commands can be listed in any order. The general form for the WAV1 command string is as follows:

"wave=sin, freq=100, ampl=5.0,.... output=on"

After the initial module set-up, the command string can consist of a single sub-command to program the new value. In this respect, all the sub commands are optional, and user need only reprogram the parameter(s) associated with the desired change.

The command string may also be entered as "reset", which will restore the WAV1 to the power-on default status. Default values are as follows:

Frequency = 1 Hz selected on the 200kHz range
Amplitude = 0 volts
Output = Off
Waveform = DC
Duty Cycle = 50%
Offset = 0 volts
Stop Mode = Asynchronous stop
Global Strobe = Disabled

Table 1. General Usage of the WAV1 Driver

```
DECLARE SUB wav1 (addr&, sl%, cd$)
CALL wav1(&HCFF8, 9, "reset")
cd$ = "wave=sin, freq=1000, ampl=5.0, output=on"
CALL wav1 (&HCFF8, 9, cd$)
WHILE INKEY$="": WEND
CALL wav1 (&HCFF8, 9, "reset")
END
```

The simplest, complete QuickBASIC WAV1 control program for generating a 1kHz, 5V sine wave using the WAV1 driver is shown in Table 1.

The WAV1 driver code must be added to the program as a "sub-program". Consult the QuickBASIC documentation for more information on writing subprograms.

WAV1 Applications Examples

The use of the WAV1 driver is illustrated in the following applications for mechanical testing, control, and educational uses. The example programs assume that the IBIN interface is set to segment address &HCFF8, and that the WAV1 is mounted in slot 9.

Mechanical Test – Since the WAV1 is fully programmable, it can be used to generate complex waveforms or output patterns which can be reproduced each time the program is executed. This output must be fed to other types of amplification and actuation circuitry. Two examples are compression testing and shake table control.

Writing a Custom Driver for the WAV1 Module

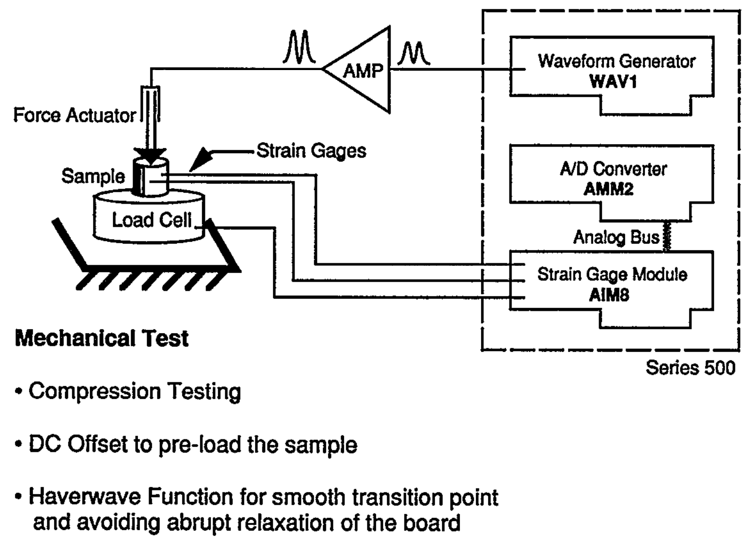


Figure 1. Compression Test Set-up

For compression testing, the WAV1 control registers enable the module to produce continuous waveforms, or a single pulse (haver sine or triangle) anywhere in the available range of frequency and duty cycle. This enables a variety of complex control voltages to be programmed and applied to an amplifier and force actuator. The actuator, in turn, applies a load to a sample under test. The WAV1's offset feature makes it possible to pre-load the sample under test. A Model 500A data acquisition system can house several WAV1 modules and strain gage cards. A fully integrated, multi-channel system can thus apply stimuli and monitor results.

A program which pre-loads the drive amplifier with -2.0 volts for five seconds, and then generates a 1Hz haver sine pulse with 10V amplitude is shown in Table 2.

Table 2. Haversine Program for Compression Testing

```
DECLARE SUB wav1 (addr&, sl%, cd$)
CALL wav1(&HCFF8, 9, "reset")
cd$ = "wave=DC, offs=-2"
CALL wav1(&HCFF8, 9, cd$)
T!=timer: while timer-t!<5: wend
cd$ = "wave=sin, freq=1, ampl=10, output=haver"
CALL wav1(&HCFF8, 9, cd$)
END
```

As a shake table controller, the WAV1 can be programmed to output various combinations of waveforms while amplitude, frequency, or other parameters are modulated in real time. As in the compression test example, the WAV1 output must be amplified, and then applied to a voice coil or other type of actuator. A relatively simple computer program can call up the various WAV1 waveforms, modulate the output, control wave durations, time delays, etc. This example applies the following test protocol:

1. 1V, 5Hz square wave for 10 seconds
2. 20Hz triangle wave with amplitude increasing from 1V to 5V in .5V steps at the rate of .5V every 30 seconds.

Table 3. Shake Table Control Output

```
DECLARE SUB wav1 (addr&, sl%, cd$)
CALL wav1(&HCFF8, 9, "reset")
cd$ = "wave=square, freq=5, ampl=1, output=on"
CALL wav1(&HCFF8, 9, cd$)
t!=timer: while timer-t!<10: wend
amplt=1.0
while amplt <= 5.0
   cd$ = "wave=tri, freq=20, ampl=" + str$(amplt)
   CALL wav1(&HCFF8, 9, cd$)
   t!=timer: while timer-t!<30: wend
   amplt=amplt + 0.5
wend
CALL wav1(&HCFF8, 9, "reset")
END
```

Writing a Custom Driver for the WAV1 Module

Electrical Control – Once programmed, the WAV1 produces a continuous output until the module is either reprogrammed or switched off. Further, one or more parameters of the WAV1's output can be modulated under program control. These features make the WAV1 a good choice for regulating the drive signal to an electrical load. The parameters most commonly used for regulation are amplitude and duty cycle. However, offset alone might be adjusted where a load requires a continuous, proportional control voltage.

One example of regulation is the adjustment of oven temperature. The system uses a Model 500A with a thermocouple module for temperature measurements and a WAV1 for control output. The software will use KDAC500/M in conjunction with the WAV1 driver. Since ovens normally require high current, a power transistor is used as the controlling pass element, with the WAV1 supplying drive to the base of the transistor. To minimize power dissipation in the transistor, it most efficient to run the transistor either saturated or cut off. Thus, a square wave output from the WAV1 is the best choice.

Regulating the transistor base drive can be accomplished by either maintaining the width of the pulses and changing frequency, or by maintaining frequency and modulating the relative on and off times for each pulse. The latter method is simpler because it requires calculation of only the duty cycle, versus frequency and duty cycle. One or more thermocouples can be attached to the oven to monitor temperatures. These temperatures are entered into a control algorithm which calculates the required duty cycle. and updates the WAV1.

Educational Applications – Frequently, computerized data acquisition is taught as part of engineering courses. The associated labs usually include many workstations, so finding systems with a good balance between performance, versatility, and cost is often a prime consideration. A Model 575 and WAV1 module are a cost-effective alternative to voltage and current meters, signal sources, bias supplies, and other instruments. The system is ideal for demonstrating basic electrical theory, as well as more complex aspects of electronics, programming, and test design.

A single WAV1 can operate as a DC source for powering or biasing low-power circuits (20mA max. at up 10 volts). This is ideal for many types of circuits based on transistors, FETs, and op-amps. As a source of square, sine, and triangle waveforms, the WAV1 can be used in studies of RMS, ripple, and load regulation. The behavior of filter networks, as well as different types of inductive and reactive loads, can also be investigated by combining the WAV1 with analog and digital I/O facilities of the Model 575. Multiple analog input channels on the Model 575 permit many test points to be monitored at aggregate speeds of up to 62.5 kHz.

The WAV1 module is fully compatible with all Keithley 500-series data acquisition systems, permitting fully integrated excitation and measurement systems. The performance of test programs will be highly reproducible because all stimuli and measurements are controlled under a single programming environment.

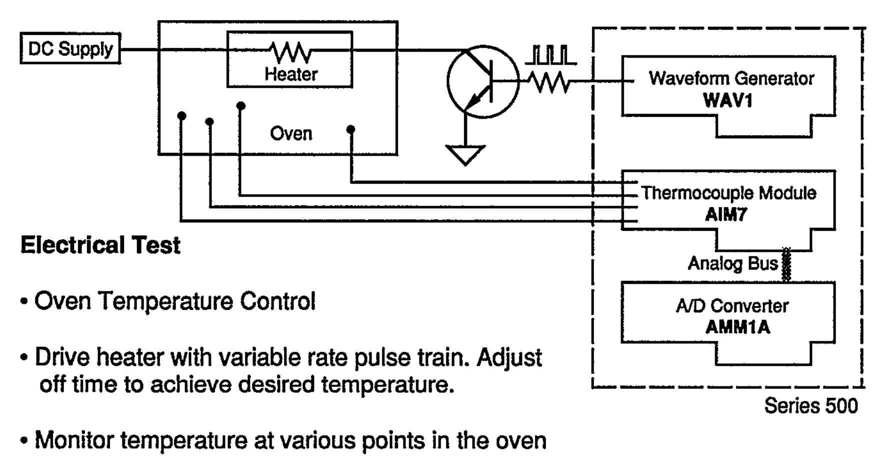
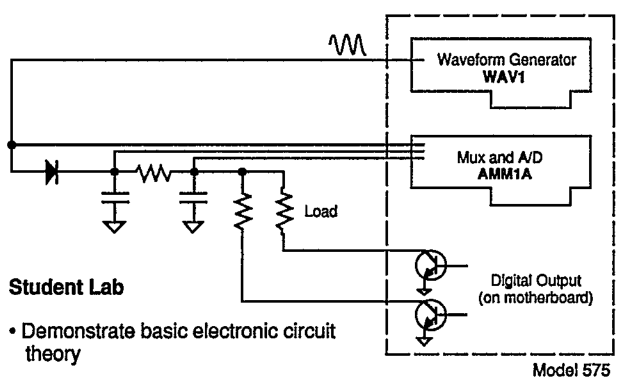


Figure 2. Temperature Regulation with the WAV1

Table 4. Controlling Temperature by Modulating Duty of the WAV1 Output

```
DECLARE SUB wav1 (addr&, sl%, cd$)
CALL wav1(&HCFF8, 9, "reset")
setpoint! = 325    ' desired temp = 325 deg C
' WARM-UP PHASE - CONTINUOUSLY ON  AT 5V OUTPUT DRIVE
cd$ = "wave=DC, offset=5"
CALL wav1(&HCFF8, 9, cd$)
'Read thermocouple in foreground while temp! < setpoint!
CALL FGREAD(......)
wend
' REGULATION PHASE - HOLD AT SETPOINT
while inkey$=""
'Read thermocouple in foreground
CALL FGREAD(......)
'Calculate duty based on difference between measured temperature and setpoint. This portion of the program
'would normally have to be fine-tuned to the application. Following equation provides up 95% duty cycle at 20
'degrees below setpoint
dut! = 5 * (setpoint! - temp)
if dut! > 95 then dut! = 95
if dut! < 5 then dut!=5: outp$="off"
if dut! => 5 then outp$ = "on"
cd$ = "wave=square, freq=1, ampl=5"
        + ", duty = " + str$(dut) +
        ", output = " + outp$
CALL wav1(&HCFF8, 9, cd$)
wend
'Turn off WAV1 and shut down control
CALL wav1(&HCFF8, 9, "reset")
END
```



Student Lab

- Demonstrate basic electronic circuit theory
- Digitizes signals at up to 62kHz
- Use software to analyze rms, average ripple and load regulation
- Use digital I/O to change circuit load
- Variable input frequency to see effects of filter time constant

Figure 3. Laboratory Workstation Using the Model 575 and a WAV1

Writing a Custom Driver for the WAV1 Module

```
'*****************************************************************************************************
' SUB wav1 (addr&, sl%, command.string$) STATIC
'*****************************************************************************************************
' QuickBASIC Subprogram for controlling the WAV1 module.

' (c) Keithley Instruments, Inc. 1990 Written in Microsoft QuickBASIC 4.5  - Guy Zumpetta 3/16/90

' Presumes that the range switch is set to 10V position. If it is set to 1V position, output and offset amplitude will be
'0.1  x programed value.

' Command Syntax:

' CALL WAV1 ( address%, slot%, command_string$ )

' Where:

' Address - (long integer) - the segment address of the interface controlling the system containing the WAV1 (e.g.
' &HCFF8).

' Slot - (integer) - the slot position of the WAV1 (1-10)

' Command strings:                                    POWER-UP
'                                                     DEFAULT
' INIt, RESet - initialize WAV1 to power-up defaults
' FREquency          = 0.1 - 200000 (Hz)              1 on 200kHz
' AMPlitude, LEVel   = 0  to 10.0 (volts)             0
' OUTput             = Enable, Disable, Haver, or Pulse   Disable
' WAVe               = SIne, TRiangle, SQuare, or DC  DC
' DUTy, CYCle        =  5 to 95 or .05 to .95         50
' OFFset             = -10.000 to +10.000 (volts)     0
' SYNc, STOpmode     = Sync or Async                  Async
' GLObal, STRobe     = Enable or Disable              Disable

 ' (Significant characters are capitalized)
' (Some parameters have other legal aliases - see the code)

 ' Include in the beginning of main program:

' DECLARE SUB WAV1( address&, slot%, command.string$ )

' Typical usage:

' CALL WAV1 (&HCFF8, 9, "wave=sine, ampl=7.5, output=on")

'  Up to 8 parameters can be entered as the command.string$. The parameters must be separated by commas as shown
' above, but can be entered in any order. If used, INIT or RESET must be used alone. After a RESet, the wave,
' frequency, amplitude, and enable are the minimum commands to output a waveform. The other parameters will
' remain at defaults.
'*****************************************************************************************************
```

```
    DEFINT A-Z
    STATIC wavt$, freq!, rng&, ampl!, duty%, offs!, outp$, stpm$, strb$
    STATIC ss%, en%, fs%, gs%, rs%, ah%, al%
    STATIC op%, oh%, ol%, ruh%, rul%, rdh%, rdl%

' Set defaults for the parameters which may not be set through the CALL

    rs% = 0: rng& = 200000
    IF duty% = 0 THEN duty% = 50
    IF freq! = 0 THEN freq! = 1: rng& = 200000

' Parse the command.string$ for the knob(s)

    cmd.str$ = LTRIM$(RTRIM$(LCASE$(command.string$)))

    DIM wavcmds$(12)
    index% = 0

    FOR commapt% = 1 TO LEN(cmd.str$)
        IF MID$(cmd.str$, commapt%, 1) = "," THEN
            wavcmds$(index%) = LEFT$(cmd.str$, commapt% - 1)
            cmd.str$ = RIGHT$(cmd.str$, LEN(cmd.str$) - commapt%)
            cmd.str$ = LTRIM$(RTRIM$(cmd.str$))
            index% = index% + 1
            commapt% = 1
        END IF

    NEXT commapt%

    wavcmds$(index%) = cmd.str$

    FOR pass% = 0 TO index%

        eqposn% = INSTR(wavcmds$(pass%), "=")
        op$ = LTRIM$(RIGHT$(wavcmds$(pass%), (LEN(wavcmds$(pass%)) - eqposn%)))
        knob$ = (LEFT$(wavcmds$(pass%), 3))

' Parse elements in string array "wavcmds$(pass%)" for the operation (OP$)

        SELECT CASE knob$
            CASE "ini", "res"
                fs% = 0
                ah% = 0: al% = 0
                op% = 0: oh% = 0: ol% = 0
                gs% = 0: ss% = 0: en% = 0
                ruh% = 0: rul% = 0: rdh% = 0: rdl% = 0
                duty% = 50
                freq! = 1: rng& = 200000
                ' LOCATE 25, 1: PRINT "WAV1 STATUS: Initialized and ready";
                GOTO poke.values
            CASE "wav"
                wavt$ = LEFT$(op$, 2)
```

```
        SELECT CASE wavt$
            CASE "dc"
                fs%=0
            CASE "si"
                fs%=1
            CASE "tr"
                fs%=2
            CASE "sq"
                fs%=3
            CASE ELSE
                err.flag% =1 GOTO exit.wav1
        END SELECT

    CASE "fre"
        F1 = VAL (op$)
        IF f! > 200000 OR f! < .1 THEN err.flag% = 1: GOTO exit.wav1
        If duty% < 50 - f! / rng& OR duty% > 100 - 50 * f! / rng& THEN
            err.flag% = 2
            GOTO exit.wav1
        END IF
        freq! = f!

    CASE "dut", "cyc"
        d! =VAL (op$)
        if d! , 1 THEN d% = INT(100 * d!) ELSE d% = INT(d!)
        IF d% < 5 OR d% > 95 THEN
            err.flag% = 2
            GOTO exit.wav1
        END IF
        duty% = d%

    CASE "amp", "lev"
        a! = VAL (op$)
        IF a! < 0 OR a! > 10 THEN
            err.flag% = 1
            GOTO exit.wav1
        END IF
        ampl! = a!
        bits% = (ampl! / 10) * 4095
        ah% = bits% \ 256
        al% = bits% MOD 256

    CASE "off"
        o! = VAL (op$)
        IF o! < -10 OR o! > 10 THEN
            err.flag% =1
            GOTO exit.wav1
        END IF

        op% = 0
        offs! = o!
        IF offs! < 0 THEN op% = 1: offs! = ABS(offs!)
```

```
            bits% = (offs! / 10) * 4095
            oh% = bits% \ 256
            ol% = bits% MOD 256

        CASE "out"
            outp$ = LEFT$(op$, 2)
            SELECT CASE outp$
                CASE "of", "di", "0"
                    en% = 0
                CASE "on", "en", "1"
                    en% = 1
                CASE "pu", "ha", "2"
                    en% = 2
                    ss% = 1
                CASE ELSE
                    err.flag% = 1: GOTO exit.wav1
            END SELECT

        CASE "sto", "syn"
            stpm$ = LEFT$(op$, 1)
            SELECT CASE stpm$
                CASE "a", "d", "0"
                    ss% = 0
                CASE "s", "e", "1"
                    ss% = 1
                CASE ELSE
                    err.flag% = 1: GOTO exit.wav1
            END SELECT

        CASE "glo", "str"
            strb$ = LEFT$(op$, 1)
            SELECT CASE strb$
                CASE "d", "0"
                    gs% = 0
                CASE "e", "1"
                    gs% = 1
                CASE ELSE
                    err.flag% = 1: GOTO exit.wav1
            END SELECT
        CASE ELSE
            err.flag% = 1: GOTO exit.wav1
    END SELECT
NEXT pass%

' Select range bits based on desired input freq
IF freq! <= 200000 THEN rs% = 0: rng& = 200000
IF freq! <= 20000 THEN rs% = 1: rng& = 20000
IF freq! <= 2000 THEN rs% = 2: rng& = 2000
IF freq! <= 200 THEN rs% = 3: rng& = 200
IF freq! <= 20 THEN rs% = 4: rng& = 20
IF freq! <= 2 THEN rs% = 5: rng& = 2
```

```
calc.ramps:
    ru.bits& = INT((freq! * 2 ^ 11 - 1) / (rng& * (1 - (duty% / 100))))
    rd.bits& = INT((freq! * 2 ^ 11 - 1) / (rng& * (duty% / 100)))

' See if either ramp exceeds 4095 and toggle up one range if necessary

    IF (ru.bits& > 4095 OR rd.bits& > 4095) THEN
        rng& = rng& * 10
        rs% = rs% - 1
        GOTO calc.ramps
    END IF

' Check again that the range select and total ramp up/down values are legal

    IF rs% < 0 THEN err.flag% = 3: GOTO exit.wav1
    IF ru.bits& > 4095 THEN ru.bits% = 4095: err.flag% = 2
    IF rd.bits& > 4095 THEN rd.bits% = 4095: err.flag% = 2

'Set up the high nibbles and low bytes only if no errors have been detected

    ruh% = ru.bits& \ 256
    rul% = ru.bits& MOD 256

    rdh% = rd.bits& \ 256
    rdl% = rd.bits& MOD 256

poke.values:

'Set up CMDA and CMDB and POKE out the information

    DEF SEG = addr&
    cmnd.a& = 2 * (sl% - 1)
    cmnd.b& = cmnd.a& + 1

    POKE cmnd.a&, (7 * 32) + rdh%
    POKE cmnd.b&, rdl%

    POKE cmnd.a&, (6 * 32) + ruh%
    POKE cmnd.b&, rul%

    POKE cmnd.a&, (5 * 32) + (op% * 16) + oh%
    POKE cmnd.b&, ol%

    POKE cmnd.a&, (4 * 32) + ah%
    POKE cmnd.b&, al%

    POKE cmnd.a&, (1 * 32) + gs% * 8 + rs%

    IF en% = 0 OR en% = 1 THEN
        POKE cmnd.a&, (0 * 32) + (ss% * 8) + (en% * 4) + fs%
```

```
    ELSEIF en% = 2 THEN
        POKE cmnd.a&, (0 * 32) + (ss% * 8) + (0) + fs%
        POKE cmnd.a&, (0 * 32) + (ss% * 8) + (4) + fs%
        POKE cmnd.a&, (0 * 32) + (ss% * 8) + (0) + fs%
    END IF

exit.wav1:

    IF err.flag% = 1 THEN
        SOUND 1000, 1
        LOCATE 25, 1
        PRINT "ERROR 1: WAV1 function '"; wavcmds$(t%); "' is illegal or out of limits        ";
    END IF

    IF err.flag% = 2 THEN
        SOUND 1000, 1
        LOCATE 25, 1
        PRINT "ERROR 2: Frequency '"; f!; "' out of limits for duty cycle '"; duty%; "'      ";
    END IF

    IF err.flag% = 3 THEN
        SOUND 1000, 1
        LOCATE 25, 1
        PRINT "ERROR 3: Frequency '"; freq!; "' out of limits for duty cycle '"; duty%; "'   ";
    END IF

    err.flag% = 0

' DEF SEG back to 20 (or appropriate value if Keithley software is not used).

    ERASE wavcmds$
    DEF SEG = 20

END SUB
```

Writing a Custom Driver for the WAV1 Module

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