Thurlby DSA524

digital storage adaptor

OPERATING MANUAL AND TUTORIAL

V2.0

Thurlby

INTRODUCTION

This manual is divided into four sections as follows:
Section 1 is the main reference section which contains a detailed description of the operation of each function.
Section 2 is a tutorial for new users (or for existing users needing examples of how functions operate).
The Appendices provide additional detail on some of the more complex functions and on some of the theoretical aspects of digital storage.
The Specifications give detailed technical specifications for the instrument, plus service and warranty details.
N.B. The DSA524 can use either an oscilloscope or a personal computer (IBM compatible) as the display device. This manual only covers use with an oscilloscope. To use a PC as the display device the "DS-PC Link" software package must be purchased, an additional manual is supplied with this software.

FIRMWARE LEVEL

From time to time small revisions may be made to the firmware of the DSA524 (the firmware is the ROM based program code for the unit).

The firmware level is displayed briefly whenever the unit is first switched on (and when SET 'SCOPE is used) as DSA524 X.XX, where X.XX is the firmware level.

This issue of the operating manual applies to units with a firmware level of 2.71 and above.

IT IS VERY STRONGLY RECOMMENDED THAT NEW USERS START BY FOLLOWING THE TUTORIAL.

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REFERENCE SECTION

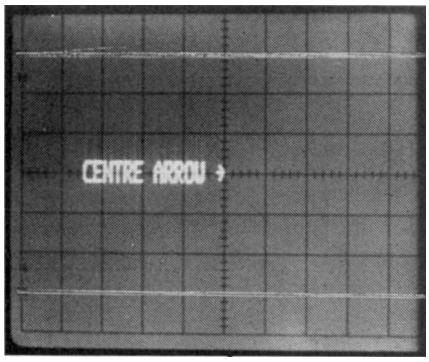
R1. CONNECTING AN OSCILLOSCOPE

Any conventional oscilloscope with an 8x10 division graticule can be used with the DSA524. Only one input channel is needed and a bandwidth of 5MHz is sufficient. The oscilloscope can be connected using a single BNC to BNC cable. Alternatively two cables can be used (see Appendix A).
Connect the rear panel socket marked "composite" to the vertical input of the oscilloscope. If a two cable connection is preferred, connect the rear panel socket marked "trigger" to the external trigger input of the oscilloscope.
Set up the oscilloscope controls as follows:-

Vertical Input:	DC coupling 100mV per division	
Timebase:	50usec per division No Sweep Hold-off	
Trigger:	Source	— as input channel (single cable connection) — or external (two cable connection)
	Mode	— normal (not bright-line auto)
	Coupling	— AC
	Slope	— negative
	Level	— negative

R2. SETTING UP THE OSCILLOSCOPE DISPLAY

Switch on the DSA524 (the power switch is at the rear) and wait while the unit performs a brief selftest and initialisation. The oscilloscope should then show a message as follows:-
"CENTRE ARROW TIP" alternating with "THEN PRESS ESCAPE"
Adjust the oscilloscope's horizontal and vertical position controls until the tip of the arrow is exactly in the centre of the screen. Two horizontal lines should be visible, one at three divisions above the graticule centre and one at three divisions below. Pressing the ESCAPE key on the DSA524 (top right-hand corner) will remove this set-up display and start normal operation.
Once the display oscilloscope has been set up, no further use need be made of its controls except for occasional re-centering of the trace to correct for any warm-up drift. To re-centre the trace press the two keys marked "SET 'SCOPE" (on the lower right of the DSA) and adjust the oscilloscope's position controls to centre the arrow tip. If problems occur when setting up the display read Appendix A.



The oscilloscope setup display.

R3. FRONT PANEL CONTROLS

All of the controls, including the rotary ones, are monitored by a microprocessor which then performs the control. All of the switches are of a momentary non-latching "key" type whose status is indicated either by lamps under the panel or, where appropriate, by text on the display. Each rotary control is enabled or disabled by the key to its right. The control is enabled when the lamp above the key is off, and is disabled when the lamp is on.
The keys within the numeric keypad section (right-hand side of unit) have up to three functions. The normal function is printed in black above each key. After the SHIFT control is pressed the function becomes as printed in green above the key. When a function ending in (NN) is pressed (e.g. SAVE(NN)) the key will enter the number printed alongside it.
Note that when SHIFT or a function ending in (NN) is pressed, the lamp marked ENTER will flash to indicate that one or more further key presses is required. Any function that causes the ENTER lamp to flash can be cancelled by pressing that function key again.
Note that some of the functions (including SET 'SCOPE) automatically set the RUN/HOLD function to HOLD. If digitising ceases unexpectedly check to see if you have unintentionally set RUN/HOLD to HOLD.
All of the front panel settings are retained when the power is turned off (except for RUN/HOLD which is always set to HOLD at power-on).

R4. ESCAPE AND RESET

The ESCAPE key is used to terminate some of the functions of the DSA such as "SET PLOT" and "SET AVG". At other times it has no effect except after SHIFT has been pressed.
Pressing SHIFT followed by ESCAPE gives the RESET function. RESET places the DSA into a known state. It cancels all of the more complex functions and sets the DSA into a state which makes it easy to display the input signals.

The main effect of RESET is to set up the unit as follows:-

RUN /HOLD	RUN.
CH1 and CH2	Coupling: AC, Volts/div: 1V, Offset: ZERO, On/off: ON.
TRIGGER	Run/hold: RUN, Source: CH1, Mode: AUTO, Level: ZERO, Slope: POS, Coupling: AC.
TRACES A and B	Trace A source: CH1, Trace B source: CH2, Gain variable: CAL, Position: HOME.
TIMEBASE	Time/div: 20usec.
ALL OTHER FUNCTIONS	OFF.

After pressing RESET the DSA will be set such that the CH1 signal is displayed on trace A and the CH2 signal on trace B. The display will be updated about three times per second. The input sensitivity will be set at 1V per division. The timebase will be set to 20usec/div. The input sensitivity and timebase speed will need to be adjusted to suit the signal.

R5. CONTROLLING DIGITISING (DATA ACQUISITION)

The digitising of the input signals is controlled by the two keys at the top of the TRIG section marked RUN/HOLD and SINGLE. When RUN/HOLD is set to RUN, the DSA is automatically re-armed following each acquisition. Thus digitising is repeated continuously provided that triggering is active (see Section R9 Trigger — Mode).
When RUN/HOLD is set to HOLD, digitising is stopped and the contents of the digitising memories is frozen. When set to HOLD, the DSA can be armed for a single acquisition using the SINGLE key.
Digitising can be performed on both input signals simultaneously, or on either signal individually. Each input channel (CH1 and CH2) is enabled or disabled using the key marked ON/OFF at the top of each channel section. When one of the input channels is turned off, the digitising memory associated with that channel is frozen and digitising takes place on the other channel alone.

R6. SETTING THE TIMEBASE

The timebase of the DSA524 is somewhat different from that of a conventional real-time oscilloscope. The time per division keys, instead of setting a sweep speed, actually control the

sampling rate of the digitiser. The shorter the time per division the higher the digitising rate. After it has been stored, the digitised data is displayed as 1024 samples across the screen (100 samples per graticule division with 12 samples before and 12 samples after the graticule). Thus the time per division is equal to 100 divided by the sampling rate.

The timebase should be set in much the same way as with a real-time oscilloscope but, unlike a real-time oscilloscope, the effect of setting the timebase speed to too slow a rate can cause aliasing effects on the display (see Appendix B). For this reason if the signal frequency is unknown a fast timebase speed should be selected initially.

Alternatively, if the signal is repetitive, the AUTOSET facility can be used. It is fully described at the end of this section.

As well as setting the digitising rate, the time per division keys also set the digitising mode. There are three modes:

NORMAL MODE: 100msec to 5usec per division (1KS/s to 20MS /s sample rates) suitable for single or repetitive events. The screen is updated after each digitising is completed.

ROLL MODE: 200msec to 200 minutes per division (500S/s to 8.3mS/s sample rate). Suitable for single or repetitive events. The screen is updated continuously. As digitising takes place, new data is written onto the right-hand side of the screen and old data disappears from the left-hand side. Thus the waveform appears to "roll" across the screen similarly to a strip chart recorder. (See Section R14. Roll Mode Operation.)

REPEAT MODE: 2usec to 50nsec per division (50MS/s to 2GS /s equivalent sample rate). Suitable for repetitive events only. The screen is updated more slowly than in normal mode. The signal must be repetitive and must be generating a trigger signal. Auto free-run (trigger mode = AUTO) is not available in repeat mode, neither is LINE trigger. (See Section R15. Repeat Mode Operation.)

The time per division keys will autorepeat if held. When a change in timebase speed causes a mode change a "beep" will be heard. ROLL and REPEAT (RPT) modes are indicated by front panel lamps.

When CH1 and CH2 are ON simultaneously the DSA524 uses a single high speed digitiser to digitise both signals. For timebase speeds of 20usecs per division and slower, both signals are digitised together using a very high speed chopping technique. For timebase speeds of 10usecs per division and faster the signals are digitised separately on alternate trigger events. The CHOP and ALT lamps show which mode is being used.

AUTOSET: The autoset function can be used to automatically set the timebase speed so as to avoid aliasing effects. The input signal must be repetitive and be generating a trigger signal whose repetition rate is between 50Hz and 5MHz.

To initiate autoset press the two keys in the timebase section marked AUTOSET simultaneously. If the trigger rate is between 50Hz and 1MHz the timebase will be reset to a position that gives between 4 and 10 trigger events across the screen. The AUTO lamp will illuminate for 3 seconds and the display will show the message "AUTOSET SUCCESSFUL" for 3 seconds.

If the trigger rate was below 50Hz the timebase setting will remain unchanged, the AUTO lamp will not illuminate and the display will show the message "TRIGGER RATE TOO LOW" for 3 seconds.

If the trigger rate was above 1MHz the timebase will reset to 1usecs/div, the AUTO lamp will illuminate for 3 seconds, the display will show the message "TRIGGER RATE ABOVE 1MHz" and the DSA will "beep" to indicate that the timebase speed may need to be set faster.

R7. CH1 AND CH2

The two input channels are identical. The input sensitivity is variable between 10V and 2mV per division. The maximum bandwidth is 35MHz down to 20mV/div, 20MHz at 10mV/div, 10MHz at 5mV/div and 5MHz at 2mV/div. The volts per division keys autorepeat if held. The input coupling can be AC (3db = 5Hz) or DC.

When both keys are pressed simultaneously the unit enters an AUTORANGING mode whereby the sensitivity is automatically set to maintain a peak to peak signal amplitude between 2 and 4 divisions. The AUTO lamp is then illuminated. To leave auto-ranging mode press either key. Autoranging does not operate in "roll" or "repeat" timebase modes.

The digitiser has an input dynamic range equivalent to ± 4.25 screen divisions. To maintain the input signal within this range an OFFSET control is provided which has a range of ±8 divisions. OFFSET can be set to zero by pressing the ZERO/(VAR) key. Press it again to return to variable offset.

If the signal goes outside the dynamic range of the digitiser while digitising is taking place the AUTO/OVLD lamp flashes to show that a signal overload is occurring. Signal values which exceed the dynamic range will be digitised as either + 4.25 divs or - 4.25 divs. Note that the lamp will continue to flash when the waveform is "held" even if the signal overload is removed.

The input amplifiers have an automatic system for removing offset errors. If the GND and AC/DC keys are pressed simultaneously an "autocalibration" takes place which re-checks and removes offset errors from every volts/div position. AUTOCAL should be used when the unit has warmed up, i.e. after about 20 minutes.

Each channel has an ON/OFF key. The operation of these keys is explained in the next section (Digitising Memories).

R8. DIGITISING MEMORIES

Each channel has its own digitising memory of 4K words. When both channels are turned ON (using the channel ON/OFF keys), both memories are updated whenever digitising is performed. When one channel is turned OFF, the contents of its digitising memory is frozen and only the memory for the other channel is updated.

The contents of the digitising memories is unaffected by the settings of the trace controls. The digitising memories are non-volatile i.e. their contents are not destroyed when the power is turned off.

Note that if either of the digitising memories is storing a waveform which gave rise to an overload condition, the OVLD lamp will continue to flash until the memory is overwritten with a waveform which is within the dynamic range of the digitiser.

R9. TRIGGER

The trigger circuitry of the DSA is broadly similar to that of a real-time oscilloscope. The trigger signal defines the exact moment at which digitising takes place. Control of the trigger circuit defines which part of a waveform will be stored.

Many functions are similar to those of a conventional oscilloscope:

SOURCE: Can be from CH1, CH2 or EXT (external trigger BNC socket).

MODE: AUTO — similar to "Bright Line Auto", the digitiser free runs if there is no trigger or if the trigger repetition rate is below 20Hz. If the rate is above 20Hz digitising takes place in synchronism.

NORM (Normal) — digitising is always in synchronism with the trigger signal. If there is no trigger signal digitising stops.

LINE — digitising is in synchronism with AC line rate (50 or 60Hz).

N.B. The trigger modes operate differently when the timebase is set to "roll" mode (see Section R14. Roll Mode Operation).
Neither Auto nor Line are available when the timebase is set to "repeat" mode (see Section R15. Repeat Mode Operation).

LEVEL: Variable over ±4 divisions. Press ZERO/(VAR) key to set zero level triggering, press again to return to variable.

SLOPE: Can be POS (positive edge triggered) or NEG (negative edge triggered).

COUPL: Can be AC, DC or HFREJ (high frequency reject). With TV and video signals, use AC for Line sync and HFREJ for Frame sync.

N.B. The lamp marked TRIG, to the right of the SINGLE key, indicates the presence of a trigger signal.

Other functions are specific to the digital storage function:

RUN/HOLD: RUN — enables continuous digitising with synchronism defined by the trigger mode control. The previous contents of both digitising memories are overwritten unless one has already been frozen using the channel ON/OFF key.

HOLD — disables digitising. The contents of both digitising memories are frozen.

SINGLE: Only operates when RUN/HOLD is set to HOLD. Enables a single update of the digitising memory with synchronism defined by the trigger mode control.

EVENTS DELAY: Sets a number of trigger events (0 to 15) which must occur before a trigger is sent to the digitiser. This allows delayed triggering on complex single-event waveforms, and can be used to avoid mis-triggering of complex repetitive waveforms (similarly to Sweep Hold-off on a real-time oscilloscope). Pressing either key shows the existing value on the display for three seconds. Repeated pressing increments or decrements the number, the keys auto-repeat if held. To rapidly turn events delay off (i.e. to 00) press both keys simultaneously.

Note that when using AUTO trigger mode, events delay will increase the minimum frequency at which it can be used from 20Hz to (1 + 20Hz, where n is the number of events.

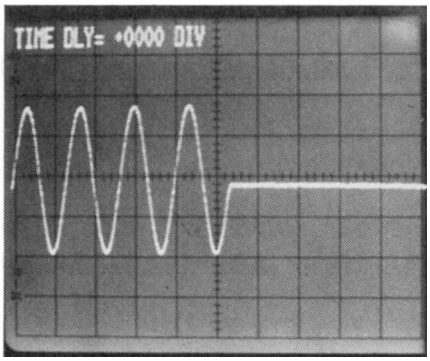
TIME DELAY: Sets the time delay between the trigger event and the start of the digitising process. The delay is measured in screen divisions and can be positive (POST TRIGGER DELAY) or negative (PRE TRIGGER DELAY).

POST — this acts similarly to sweep delay on a real-time oscilloscope. By adding time delay and then selecting a faster timebase speed, a section of a waveform occurring long after the trigger event can be examined. For "normal" mode timebase speeds (100msec/div to 5usec/div) the number of divisions of post-trigger delay is automatically increased or decreased to maintain a constant time delay when the timebase speed is changed (within a limit of 9,999 divisions maximum).

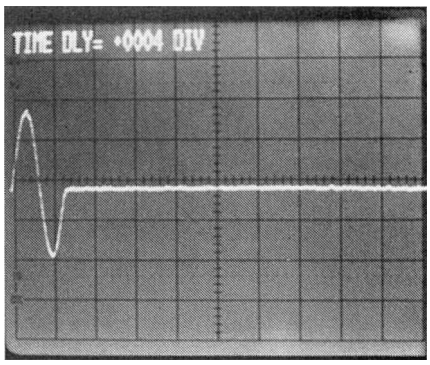
PRE — there is no equivalent to pre-trigger on a real-time oscilloscope. Pre-trigger allows the part of the waveform which occurred before the trigger to be stored and observed. The maximum pre-trigger delay is —40 divisions.

Pressing either key shows the existing value of delay on the screen for three seconds. Repeated pressing increments or decrements the number, the keys autorepeat if held. To rapidly turn time delay off (i.e. to 0000) press both keys simultaneously.

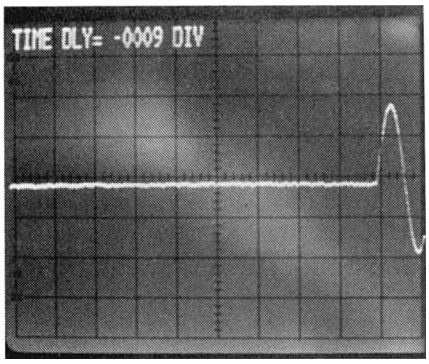
N.B. Neither pre nor post trigger delay is available in "repeat" mode. In "roll" mode only post trigger delay is available. See Section R14. Roll Mode Operation for an explanation.



A waveform burst (4 cycles) captured with no trigger time delay.



The same waveform burst captured with 4 divisions of post trigger delay.



The same waveform burst captured with 9 divisions of pre trigger delay.

R10. TRACE A AND TRACE B

The DSA524 can display two traces simultaneously, the traces are called A and B. Each trace has its own 1K word memory which can be loaded with data either from the corresponding digitising memory (CH1 for trace A or CH2 for trace B) or from an indexed waveform memory.

The trace controls operate on the waveform after it has been digitised but before it has been 'displayed. Therefore they can be used to modify waveforms recalled from a waveform store as well as waveforms taken from the digitising memories of the input channels.

POSITION: Enables the vertical position of the trace on the display to be adjusted. Pressing the HOME/(VAR) key toggles between fixed position (HOME) and variable position.

GAIN VARIABLE: Enable intermediate sensitivity levels to be set. Pressing the CAL/(UNCAL) key toggles between calibrated gain (X1) and variable gain (X1 to X0.2).

CH1 (or CH2): Pressing this key causes the trace to display the contents of the digitising memory for the corresponding input channel.

RCL(NN): (Recall indexed waveform memory). Pressing this key followed by a two digit number on the keypad causes the trace to display the contents of the corresponding waveform memory. It also sets RUN /HOLD to HOLD.

OFF: Pressing the CH1 (or CH2) and RCL(NN) keys simultaneously turns the trace off (the CH key should be pressed first, otherwise RUN/HOLD will be set to HOLD).

INV(Invert): Applies to Trace B only. Causes the waveform to be displayed inverted.

ADD B: Applies to Trace A only. Displays the sum of what is presently on Trace B and what was previously on Trace A.

SAVE(NN): Pressing this key followed by a two digit number causes the waveform presently displayed on that trace to be stored in the corresponding waveform memory. It also sets RUN/HOLD to HOLD.

R11. MEMORY SEARCH (COMP/SCAN/MAG)

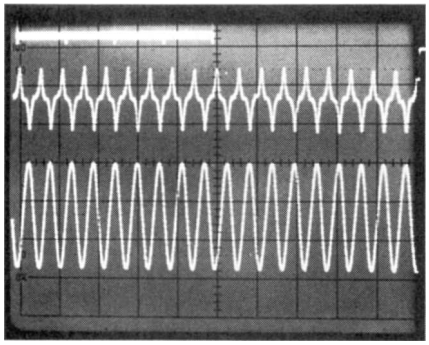
Although the size of each trace memory is 1K words (equivalent to 10.24 divisions across the screen) the size of each digitising memory is 4K words (equivalent to 40.96 divisions). Normally each trace memory is filled with the first 1K words from the corresponding digitising memory. (Note that in "roll" mode it is the last 996 words — see Section R14. Roll Mode Operation.)

To enable all of the digitising memory to be viewed, a SEARCH key is provided next to the timebase section. Pressing SEARCH cycles through three states as detailed below. The actual mode is indicated both by a corresponding front panel lamp and by a diagram on the display which remains there for three seconds after the mode has been changed.

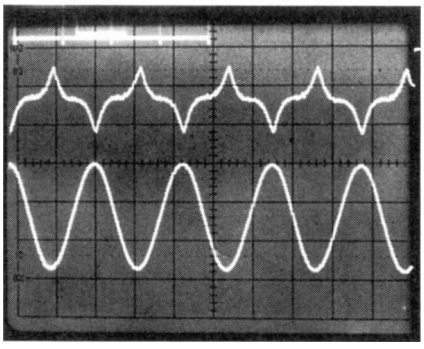
COMP: Compresses all 4K words of the digitising memory into the 1K words of the trace memory by transferring every fourth word.

SCAN: Enables any 1K section of the digitising memory to be transferred to the trace memory via a moveable window. The window is moved using the two keys marked SCAN/MAG. The position of the window is shown graphically on the display for three seconds whenever either key is pressed. Repeated pressing of either key moves the window left or right in one division (100 word) steps. The keys autorepeat if held.

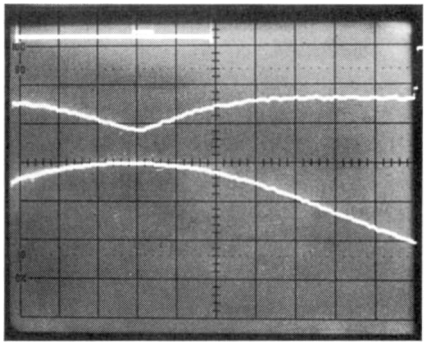
MAG: Digitally magnifies any 100 word section of the trace memory by ten so that it fills the display. The section is selected via a moveable window which is moved using the two keys marked SCAN/MAG. The position of the window is shown graphically on the display for three seconds whenever either key is pressed. Repeated pressing of the key moves the window left or right in half division (50 word) steps. The keys autorepeat if held.



A captured waveform displayed using Compress mode.



The same waveform displayed using Scan mode.



The same waveform displayed using Magnify mode.

To leave SEARCH mode and set the display mode back to normal, press the two SCAN/MAG keys simultaneously.

If one of the traces is displaying a waveform recalled from an indexed waveform memory when SEARCH is selected, the recalled waveform will remain unaffected.

R12. INDEXED WAVEFORM MEMORIES

The DSA524 has sixteen 1K word memories for temporary or permanent storage of waveforms. Each memory is identified by a two digit number from 01 through to 16. The memory is supported by trickle charged Ni-Cad batteries which will remain charged for several months should the unit be left unpowered.
To store a waveform in an indexed memory, obtain the required waveform on the display and press the SAVE(NN) key for the appropriate trace. This will cause the ENTER lamp above the numeric keypad to flash. Enter the two digits corresponding to the required memory position, the display will show "MEMORY NN = TRACE A (or B) for 3 secs.

Note that the waveform is stored exactly as it appears on the display except for its vertical position which is stored as it would be if the trace position control was at HOME.

To recall a waveform from an indexed memory, press the RCLINN) key for the trace on which the waveform is to be displayed. This will cause the ENTER lamp above the numeric keypad to flash. Enter the two digits corresponding to the required memory, the display will show "TRACE A (or B) = MEMORY NN" for 3 secs.

When a waveform recalled from an indexed memory is being displayed, the MEM lamp on the corresponding trace will be illuminated. The memory number from which it was recalled can be checked by pressing the RCLINN) key twice.

Any trace recalled from a waveform store is temporarily suppressed when in "roll" mode RUN or SINGLE.

R13. DISPLAY UPDATE RATE

In "normal" mode (timebase speeds between 100msec and 5usec per division) the display update rate can be varied. This is done with the key marked RATE (within the timebase section).

The default update rate (NORM) re-starts the digitising process about 300msecs after the completion of the previous one. This gives a display update rate of about 3 per second for higher timebase rates, slowing down as the timebase speed gets into the tens of milliseconds (at 100msec per division digitising takes 4 seconds).

Pressing the RATE key once enters SLOW update mode. This increases the delay from 300msec to 3secs giving more time for each digitising of the waveform to be observed carefully. Pressing the key again returns to normal update rate.

Holding the RATE key depressed for two seconds enters FAST update mode. This reduces the delay from 300msec to 20msec giving a virtually instant update which mimics a real-time oscilloscope. Pressing the key again returns to normal update rate.

Entering FAST update mode reduces the acquisition memory size to 1K words per channel and disables all of the trace control functions except for trace position. Search mode (COMP/ SCAN/MAG) and Average (AVG) are also disabled.

When RUN/HOLD is set to HOLD, the remaining 3K words per channel of the digitising memory are set to zeroes and the disabled functions are restored. Pre-trigger time delay is limited to 10 divisions in FAST mode.

In "roll" and "repeat" modes the RATE key is disabled.

R14. ROLL MODE OPERATION

In "roll" mode new data is written onto the right-hand side of the display as digitising takes place. Thus the waveform appears to roll across the screen. The operation of the DSA524 in "roll" mode (timebase speeds of 200msecs and below) is different from its operation in other modes in several respects:

a) Triggering and Display Update Rate

Because the waveform data is written continuously onto the display, it is not necessary to continually stop and restart the digitising process. Consequently when RUN /HOLD is set to RUN, digitising takes place continuously and triggering is disabled. The RATE key is disabled.

When RUN/HOLD is set to HOLD, triggering is enabled for operation via the SINGLE key. Pressing SINGLE commences the "roll" and the trigger event stops it, thus the waveform data captured is entirely pre-trigger data. Consequently if a trigger occurs immediately, no data will be captured unless some post-trigger time delay has been set. When the trigger mode is set to AUTO, triggering occurs immediately. When the trigger mode is set to NORM, triggering occurs synchronously with the trigger signal.

Because in "roll" mode the trigger stops the digitising process instead of starting it, all the data in the digitising memory is pre-trigger data unless some post-trigger time delay has been set. Pre-trigger time delay is therefore not needed and is disabled.

b) Display Window and Search mode

Because the waveform data is written continuously to the screen as digitising takes place, the display shows the last part of the 4K digitising memory instead of the first part. Because the left hand edge of the display window is set in steps of 100 words, only 996 words are displayed and the remaining 28 words are set to zero. SEARCH can only be selected in HOLD, and the scan window is initially set fully to the right instead of fully to the left.

c) Trace Controls

When in roll mode, operation of any of the trace controls (e.g. gain variable) will effect only the waveform data on the display which was captured after the control was changed. However, when the digitising process is stopped, the new trace control values will be applied to the whole of the contents of the digitising memory including waveform data captured before the change was made.

R15. REPEAT MODE OPERATION

In normal mode the DSA524 can digitise a waveform at up to 20MS /s digitising rate, equivalent to 5usecs per division. If the waveform is repetitive (as opposed to being a single event) it can digitise the waveform repetitively, gradually building up the data in the digitising memory. This mode of operation, known as "repeat" mode, is used for timebase speeds of 2usecs and above and provides equivalent digitising rates of up to 2GS /s (50nsecs per div.). The operation of the DSA524 in repeat mode is different from its operation in normal mode in several respects:

a) Triggering

Repeat mode requires a synchronously triggered waveform, AUTO and LINE trigger modes are therefore disabled. Time delay is not available (neither pre nor post trigger). The trigger event is not captured, the first section of the waveform captured starts 350 nanoseconds after the trigger event.

b) Display Update Rate

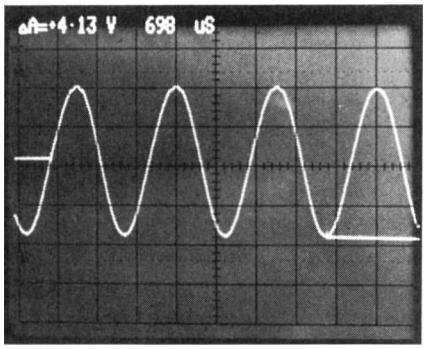
Repeat mode involves complex manipulation of data which can take several seconds per digitisation. The display update rate varies between about one per second for a single channel at 2usecs/div to one every 10 seconds for both channels at 50nsecs/div. The Rate key is disabled in repeat mode.

R16. CURSOR MEASUREMENT

Moveable cursors allow accurate measurements of voltage and time to be made on either Trace A or Trace B via an on-screen digital readout.

To select cursor measurement, press the key marked ON/OFF within the numeric keypad. Cursors will appear on Trace A, and Trace B will be suppressed. Pressing the key marked A/ B selects Trace B instead of Trace A. To turn cursor measurement off press the ON/OFF key again.

Cursor measurement.



The cursors are flashing horizontal lines which each terminate at a point on the waveform. The reference cursor is on the left hand side of the screen, the delta cursor is on the right hand side. The measurement is made between the two lines. The readout shows the voltage and time difference between the end of the reference cursor line and the start of the delta cursor line. The cursors are moved using the arrow keys marked REF CURS and Δ CURS respectively.

R17. PROGRAM MODE

The DSA524 can operate as a fully programmable instrument. It can "learn" individual or sequential front panel settings, store them in non-volatile memory, and "replay" them on demand. Up to 50 settings can be stored.

Each front panel setting includes the state of every key and rotary control and the source of each trace waveform. Thus if a setting is "learned" which includes a trace recalled from a waveform store, that same store will be recalled again when the setting is "re-played". Thus reference waveforms can be recalled automatically within PROGRAM mode.

To "learn" one or more settings press the LEARN key, this turns on learn mode. The display will show the message "NEXT POSITION = NN" for 3 seconds where NN is a number between 01 and 50 corresponding to the position set when the unit was last used.

To store a front panel setting in this position, ensure that the front panel is set as required and press the SET/NEXT key. The display will show the message "STORED IN NN" followed by "NEXT POSITION = NN + 1". To store another front panel setting, reset the front panel as required and press the SET/NEXT key again. To store the setting in any other memory position, press the SET(NN) key followed by a two digit number between 01 and 50.

The next memory position can be checked at any time by pressing the LEARN key again.

To "replay" one or more settings press the REPLAY key, this turns on replay mode. The display will show "NEXT POSITION = NN" as for learn mode. To replay the front panel setting corresponding to this position press the SET/NEXT key. The display will show "REPLAYED FROM NN" followed by "NEXT POSITION = NN + 1". Press the SET/NEXT key again to replay this next position. To replay any other position press the SETINN) key followed by a two digit number between 01 and 50.

The next memory position can be checked at any time by pressing the REPLAY key again.

Whenever the front panel is set using the replay mode all the rotary controls become inoperative. To make any rotary control operative again press the key directly to its right. (Press once if the lamp above the key is on, or twice if it is off.)

To exit either learn or replay modes press the LEARN and REPLAY keys simultaneously.

R18. SINE INTERPOLATION

When the display mode is set to MAG (magnify) the number of true samples shown across the screen is reduced to 102. Although 1,024 samples are displayed, 9 samples out of each block of 10 are mathematically calculated using linear interpolation.

Linear interpolation provides a good reconstruction of the original waveform provided that either the number of samples per cycle of the waveform is reasonably high (i.e. ten or more) or, if the number of samples is low, that the original waveform is made up mainly of linear elements (e.g. pulse, sawtooth, triangle waveforms).

When the waveform is basically sinusoidal and the number of samples per cycle is low, linear interpolation will not provide a satisfactory reconstruction and sine interpolation should be used instead. Sine interpolation uses a mathematical curve fitting algorithm and can provide a near perfect reconstruction of a sine wave from only four samples per cycle. See Appendix C for a detailed discussion of interpolation.

Pressing the SINE INTERPOLATE key toggles the function on or off as indicated by the lamp above the key. Interpolation is only active when the SEARCH mode is set to MAG. Sine interpolation slows down the display update rate considerably.

R19. AVERAGE

The RUN AVERAGE function allows a number of digitisations of the waveform to be summation averaged before being displayed. This improves the signal to noise ratio of a noisy signal and can often enable a signal to be observed that would otherwise have been masked by large amounts of HF or LF noise. The average function reduces the size of the digitising memories to 1K words per channel.

The number of waveform digitisations which are averaged can be Set to any number between 2 and 256. To change the number of readings averaged press SHIFT (key 8) followed by SET AVG (key 4). The current averaging value is shown on the display and can be incremented or decremented using the REF CURS keys (keys 2 and 3). When the required number is displayed, press ESCAPE.

Pressing the RUN AVERAGE key enables averaging, pressing the key again disables it again, the status is indicated by the lamp above the key. Acquisitions continue to be controlled by the RUN/HOLD and SINGLE keys.

When the display update rate is set to NORM the display is updated only whenever the total number of averages has been completed. When the update rate is set to SLOW the display is updated continuously as averaging takes place. The display shows the number of averages currently accumulated.

Note that averaging slows down the display update rate. This is particularly so at fast timebase speeds in "repeat" mode and slow timebase speeds in normal mode.

R20. A= AXB (TRACE MULTIPLY)

This function provides a display of the Trace A waveform multiplied by the Trace B waveform. It is particularly useful for obtaining power waveforms.

Press SHIFT (key 8) followed by AxB (key 2). The two waveforms will be multiplied together and displayed on Trace A (Trace B continues to be displayed). To return to a normal display press ESCAPE.

The multiplied waveform is scaled using units of one screen division with the centre of the screen being zero. The traces are multiplied exactly as they appear on the oscilloscope display including offsets introduced by the trace position controls. Thus at a point where the position of Trace A is +2 divs and of Trace B is —1.5 divs, the value of the multiplied waveform will be — 3 divs.

It should be noted that if either trace has values greater than ± 1 divs then overflows could occur on the multiplied waveform. The displayed waveform is limited to ± 4.25 divisions and consequently —3 divs multiplied by —2.5 divs will be displayed as + 4.25 divs instead of + 7.5 divs.

The AxB function cannot operate while digitising is taking place. Pressing the AxB key will set RUN/HOLD to HOLD. The function multiplies the traces exactly as they appear at the moment that the AxB key is pressed. When the function is enabled all of the trace controls are inoperative with the exception of the Trace A position control which can be used to adjust the position of the multiplied waveform.

R21. LINE OR DOTS DISPLAY

In line display mode the 1,024 individual points of the display are joined with angled lines to simulate one continuous line. This gives a display which is easier to view and less subject to visual aliasing than one made up of dots (see Appendix B).

Sometimes, however, it is desirable to see the exact points on the waveform where samples have been taken, along with their levels. Pressing SHIFT (key 8) followed by DOTS (key 7) causes the points to be joined by right-angled lines which form a staircase. Since the horizontal lines are brighter than the vertical ones, this gives an impression of dots and makes it easier to see each sample point and its associated level.

Also the line display may reduce the amplitude of waveforms where successive samples can have very large vertical separations. Such a waveform will also appear brighter if a dots display is used.

To return to a line display press LINE (key 7). The unit defaults to a line display after RESET.

R22. PLOT

The waveforms shown on the oscilloscope display can be sent either to a digital X-Y plotter (HP-GL compatible) using the RS-423 interface; or to an analog X-Y plotter or Y-T chart recorder using the analog plotter interface.

The plot function can be directed either to the RS-423 interface for use with a digital plotter, or to the analog plotter interface. The DSA is factory initialised for use with a digital plotter. To change to use with an analog plotter key in "function 26" (press FUNCTION NN, followed by 2 followed by 6). To return to use with a digital plotter key in "function 27".

a) Digital Plotter
The digital plotter must be compatible with HP-GL plotting commands and must be fitted with a serial interface for connection to the RS-423 interface socket of the DSA. For details of making connections and of setting the baud rate see Section R25 'RS-423 Interface'. Alternatively, if the DSA has the IEEE-488 interface option fitted, a plotter with an IEEE-488 interface may be used.

To commence plotting press PLOT (key 6), the time and voltage per division and a graticule will be plotted followed by Trace A followed by Trace B. If the plotter is a multi-pen plotter the text and the graticule will be plotted using pen 1, Trace A will be plotted using pen 2, and Trace B will be plotted using pen 3.

The entire plot fits onto an A4 sized sheet. To abandon plotting at any stage press ESCAPE.

b) Analog Plotter
The analog plotter interface is mounted on the rear panel and comprises five 4mm sockets marked X, YA, GND, YB, and PL (pen lift).

The waveforms for Trace A and Trace B are sent simultaneously to their separate output sockets along with an X axis signal for use with X-Y plotters. The 10.24 divisions of the display are plotted using a level of 100mV/div (for both Y and X) at a rate selectable as 1, 2, 5 or 10 seconds per division. The pen-lift signal is normally "low to lift" but can be inverted.

To set the plot rate, press SHIFT (key 8) followed by SET PLOT (key 5)., The oscilloscope display will show the present plot rate. Press one of the REF CURS keys (key 2 or 3) to select a new value, then press ESCAPE.

To commence plotting press PLOT (key 6). The oscilloscope display will show a series of prompts for setting the plotter. If RUN / HOLD is at RUN it will be set to HOLD. To abandon plotting before it is completed press ESCAPE.

A more complete description of the analog plotter PLOT function is given in Appendix D.

R23. PRINT

The waveforms shown on the oscilloscope display can be converted to hard-copy using a dot-matrix printer. The printer must be compatible with EPSON graphics commands (including quad density bit mapping) and must be fitted with a serial interface for connection to the RS-423 interface socket of the DSA. For details of making connections and of setting the baud rate see Section R25. Baud rates below 2400 are not recommended as the printing time becomes excessive.

The waveforms are printed with an 8x10 graticule using the same 1:1 aspect ratio as the oscilloscope display. They are preceded by several lines of text which detail the present settings of the DSA. Line feeds are arranged so that two prints will fit onto one sheet of 11 inch paper.

To commence printing, press SHIFT (key 8) followed by PRINT (key 6). RUN /HOLD will be set to HOLD and printing will commence. To abandon printing before it is completed press ESCAPE.

R24. REMOTE CONTROL AND DIGITAL DATA TRANSFER

The DSA can be fully controlled via its RS-423 serial interface or its IEEE-488 interface (if fitted). Anything that can be controlled from the front panel can also be controlled via these digital interfaces. Waveform data can be sent to and from the DSA using the interfaces, and a variety of other functions are also available.

The software commands for use on either of these interfaces are listed in Appendix F. 'Software Commands'.

R25. RS-423 INTERFACE

The DSA524 is fitted with an RS-423 serial interface which is fully compatible with equipment fitted with an RS-232C interface. It can be used for remote control of the DSA, for bidirectional data transfers and for connection to a printer or a digital plotter.

The RS-423 interface is connected via the 9 pin female D connector mounted on the rear panel. The connections are as follows:

Pin No.	Name	Function
2	RXD	Input line for sending data to the DSA
3	TXD	Output line for sending data from the DSA
5	GND	Signal ground line
7	RTS	Output line for handshaking (Request to Send)
8	CTS	Input line for handshaking (Clear to Send)

The interface operates with 8 data bits, 1 start bit, 1 or more stop bits, no parity. If hardware handshaking is not being used, pin 8 (CTS) must be pulled permanently high, this can be done by linking it to pin 7 (RTS) and forcing RTS permanently high by using function 83 (see Section R27). X-on/X-off handshaking can be used as an alternative to hardware handshaking.

The baud rate is adjustable in binary steps between 300 baud and 38,400 baud. Once set, the baud rate is stored in non-volatile memory and will remain set. As shipped from the factory it is set to 9,600 baud.

To change the baud rate press SHIFT (key 8) followed by SET BAUD (key 3). The display will show "baud rate = 9600" (for example). Use the reference cursor keys (keys 2 and 3) to increase or decrease the rate, then press ESCAPE. If the DSA is not connected to an oscilloscope the baud rate may be set directly using the FUNCTION NN key (see Section R27).

Note that as well as the options of 300 through to 38,400 there is a further option of IEEE. This option is exclusively for use when the optional IEEE-488 interface board is installed and enabled. Note that the RS-423 interface cannot be used when the IEEE-488 interface is enabled.

Further details of making connections to the RS-423 interface are given in Appendix E.

A description of the software commands for remote control and data transfer via the interface is given in Appendix F.

R26. GP-IB (IEEE-488) INTERFACE

An optional module is available which interfaces the DSA524 to the General Purpose Interface Bus (GP-IB) using the IEEE-488 standard. This option makes all of the functions which are available via the RS-423 interface also available via the GP-IB interface. The interface can be used either with a controller or without a controller in "talker only" mode for connection to a printer or digital plotter.

A full description of the fitting and operation of the GP-IB interface module is provided in the separate manual supplied with it. A description of the software commands for remote control and data transfer via the interface is given in Appendix F. 'Software Commands'.

R27. DIRECTLY ACTING FUNCTIONS

Some of the parameters of the DSA which are normally set interactively using the text readout on the oscilloscope display can also be set directly using the FUNCTION NN key. These include setting the baud rate for the RS-423 interface and setting the analog plotter rate.

A full list of these functions is given below:

Set Analog Plotter Rate	1sec /div	21
	2sec/div	22
	5sec/div	23
	10sec/div	24
Select Analog Plotter Routine auto version		25
Select Analog Plotter Routine prompted version		26
Select Digital Plotter Routine		27
Set Baud Rate	300	30
	600	31
	1200	32
	2400	33
	4800	34
	9600	35
	19200	36
	38400	37
	IEEE-488 mode	38
Turn bandwidth limiting off		80
Turn bandwidth limiting on (factory default)		81
(a bandwidth limit of about 6MHz is applied except in repeat mode)		
Enable hardware handshaking via RTS (factory default)		82
Disable hardware handshaking via RTS		83
(disabling RTS handshaking forces RTS permanently high)		

Note that the RESET function cancels the effect of Function 80.

The following functions are intended for use by Service Engineers only (in conjunction with the appropriate service manuals):

Start analog plotter calibration routine	20
Check display lamps	70
Check keyboard switches	71
Check rotary controls	72
Check DAC output waveform	73
Check RS-423 operation	74
Check Autocal values	75
Return bytes from RS-423 input buffer	76
Clear all set-up parameters	78

Function 78 can be used if the DSA appears to have suffered a program corruption from which it cannot be made to recover either by switching the DSA off or by using the RESET function. Note that the contents of all the memories including the indexed waveform stores and the PROGRAM memory will be cleared. Function 78 restores the DSA to the same state as when it left the factory.

USERS TUTORIAL

The sophisticated facilities of the DSA524 have resulted in a fairly complex instrument. This "hands-on" tutorial takes the user through most of the functions of the unit step by step, and provides an easy method of gaining familiarity with its operation.

New users should follow the tutorial exactly and resist the temptation to experiment with functions before they have been covered.

Existing users may find the tutorial useful for covering functions with which they are not yet familiar. Each section is complete in itself and commences with the DSA being "reset" using SHIFT followed by RESET, and with the signal generator being set to SINE, 20kHz, 5V pk-pk.

INDEX TO THE TUTORIAL

Equipment Required

1. A conventional real-time oscilloscope for the display, the minimum specification: 5MHz bandwidth, single channel, 8x10 division graticule.
2. A wide frequency-range signal source, preferably a function generator. (The tutorial assumes that a function generator is being used.)
3. Three BNC to BNC connecting cables.

Setting-up the Equipment

1. Connect the rear panel BNC socket of the DSA marked "composite" to the CH1 input of the oscilloscope.
2. Set the oscilloscope as follows:

Mode:	Single channel (CH1)
CH1 input coupling:	DC
Sensitivity:	100mV/div
Timebase:	50usecs/div
Trigger source:	CH1 (not vertical mode)
Trigger coupling:	AC
Trigger slope:	Negative
Trigger Level:	Negative (slightly)
Sweep delay, sweep hold-off etc:	Zero or minimum

3. Connect the main output of the function generator to the CH1 input of the DSA. Connect the Sync or TTL output to CH2.

First Steps

1 Switch on the DSA (the power switch is at the rear). The oscilloscope should then show the message "CENTRE ARROW TIP" (alternating with "THEN PRESS ESCAPE"). Adjust the trigger level if necessary.

2. Adjust the vertical and horizontal shift controls of the oscilloscope until the arrow tip is in the centre of the graticule.
3. Set the function generator to SINE, 20kHz, 5V pk-pk.
4. Press the ESCAPE key. Then press SHIFT followed by RESET. This ensures that all of the more complex functions are cancelled, and that the DSA is put into a known state as follows:

   Both channels ON, 1V /div, AC coupled, 20usec/div AUTO trigger from CH 1.

   The display should now be showing a sine waveform and a pulse waveform, each of around 5 divisions pk-pk amplitude and around 2.5 divisions period.

What to Expect

The unit is now operating as a digital storage oscilloscope. Both input signals are being repetitively digitised by an analog to digital converter (ADC), and stored in a memory the contents of which is being converted back into analog signals by a digital to analog converter (DAC) and then displayed on the screen via a display multiplexer. This process takes a little time, introducing a slight delay between a change occurring at the input and that change appearing on the display.

The display multiplexer mixes together the two traces, the trigger signal and, when needed, text. At the far left of the screen the valid section of the trace is preceded by a very narrow negative pulse followed by a horizontal line at the trace zero level (this can be removed by using a two cable connection — see Appendix A). Following the valid section, at the far right of the screen, the trace is shifted up to the top of the display area.

When the display is correctly centred, the valid section of the traces starts 0.12 divisions to the left of the graticule and ends 0.12 divisions to the right of it. If the timebase of the display oscilloscope is not perfectly calibrated, the valid section may be slightly longer or shorter than this.

Each trace is made up of 1024 samples across 10.24 horizontal divisions of the screen (100 samples per division). Each sample can be at any of 256 levels within 8.53 vertical divisions (30 levels per division).

Because the display is made up of discrete steps, waveforms do not look quite the same as they do with an analog oscilloscope. The minimum level change between samples is one thirtieth of a division, and even where the input signal level is constant the digitised level may vary slightly. This variation is caused by noise on the signal, noise in the input amplifiers, or digitising noise in the ADC (typically ±)bit) and results in the digitised waveform looking slightly "ragged" when compared with an analog oscilloscope. Noise on the waveform of an analog oscilloscope is averaged out by the eye.

The Display Oscilloscope

Once the display oscilloscope has been set up, no further use need be made of its controls except for occasional re-centering of the trace to correct for any warm-up drift. To re-centre the trace press the two keys marked "SET 'SCOPE" (on the lower right of the DSA) and adjust the oscilloscope's position controls to centre the arrow tip.

Front Panel Controls

The front panel of the DSA524 is completely "cold", that is to say that there are no direct links between the front panel and the circuitry. All of the controls, including the rotary ones, are monitored by a microprocessor which then performs the control. All of the switches are of a momentary non-latching type whose status is indicated either by lamps under the panel or, where appropriate, by text on the display. This system enables complete digital programming of the front panel when required.

The keys within the numeric keypad section (right-hand side of unit) have up to three functions. Their normal function is printed in black above each key. After the SHIFT key is pressed the function becomes as printed in green above the key. When a function ending in (NN) is pressed (e.g. SAVE(NN)) the key will enter the number printed alongside it.

Note that when SHIFT or a function ending in (NN) is pressed, the lamp marked ENTER will flash to indicate that one or more further key presses is required. Any function that causes the ENTER lamp to flash can be cancelled by pressing that function key again.

Note that some of the functions (including SET 'SCOPE) automatically set the RUN/HOLD function to HOLD. If digitising ceases unexpectedly check the condition of RUN /HOLD.

All of the front panel settings are retained when the power is turned off (except for RUN /HOLD which is always set to HOLD at power-on).

Getting out of Trouble

If at any stage you lose track of the operation of the DSA, it can be reset to a known state by pressing SHIFT followed by RESET (as in First Steps). Each section of the tutorial starts with the DSA in the "reset" state and the generator set to SINE, 20kHz, 5V pk-pk. Thus it is easy to restart the tutorial at the beginning of any section.

PART ONE — BASIC FUNCTIONS

The functions covered in this first part of the tutorial are the ones necessary to operate the DSA524 as a basic digital storage adaptor.

Controlling Digitising

(Start with the DSA reset and the generator set to SINE, 20kHz, 5V pk-pk.)

The digitising of the input signals is controlled by the two keys at the top of the TRIG section marked RUN /HOLD and SINGLE.

1. When RUN/HOLD is set to RUN, digitising is repeated continuously. Try changing the amplitude or frequency of the generator and note how the display is updated about three times each second.

2. When RUN /HOLD is set to HOLD, digitising is stopped. Press RUN /HOLD to set it to HOLD, then change the output of the generator, and note how the display remains unchanged.

3. When RUN /HOLD is set to HOLD, pressing the SINGLE key causes digitising to occur once. Press SINGLE and note how the display is updated to the new amplitude/frequency of the generator.

Controlling the Input Channels

(Start with the DSA reset and the generator set to SINE, 20kHz, 5V pk-pk.)

The two input channels CH1 and CH2 are identical. They control the levels of the input signals before they are digitised.

1. The input coupling switches (AC/DC and GND) perform the same function as on a normal oscilloscope. Try changing them. Note that when CH1 is grounded the position of the CH2 waveform on the display becomes random, this is because the trigger signal has been removed. Set both channels back to AC.

2. The input sensitivity is variable between 10V/div and 2mV /div. The key with a downwards arrow sets a lower volts/div setting and the key with the upwards arrow a higher one, the keys autorepeat if held depressed. Try changing the CH1 sensitivity upwards and downwards. Note that when the input exceeds approximately ± 4.25 divisions on the screen it becomes "clipped", this is because the range of the digitiser is limited to ± 4.25 divisions. When the input signal is outside the range of the digitiser, the AUTO/OVLD lamp flashes, this is to warn the user that the signal is not being correctly digitised (no damage is being done).

3. Autoranging input sensitivity can be selected on either channel. Press both arrow keys simultaneously, the AUTO lamp will come on. Try changing the amplitude of the generator output and note how the sensitivity is automatically changed to maintain a screen amplitude of between about 1.5 and 3.5 divisions. To cancel autoranging press either arrow key once.

4. If the DC level of the input signal is not zero, it may be necessary to apply a DC offset to the signal before it is digitised. This can be done with the rotary controls marked OFFSET which can add up to ±8 divisions of offset. Press the key marked ZERO(VAR) to enable variable offset (it is enabled when the lamp is off). Try rotating the offset control and note how the DC level of the signal is changed. Press the key again to return to zero offset.

5. The digitising for each channel can be controlled individually by the keys marked "ON/OFF". These allow one channel to be "held" while digitising continues on the other channel. Try turning CH1 off and changing the frequency of the generator, note that the CH2 display continues to be updated but that the CH1 display is frozen. Note that if both channels are turned off, RUN/HOLD will be automatically set to HOLD.

Controlling the Traces

(Start with the DSA reset and the generator set to SINE, 20kHz, 5V pk-pk.)

The DSA524 can display two traces simultaneously, the traces are called Trace A and Trace B. Whereas the input channel controls (CH1 and CH2) operate on the input to the digitiser, the trace controls operate on the output signals which are sent to the display oscilloscope. Normally Trace A is used to display CH1, and Trace B is used to display CH2, but the traces may alternatively be used to display waveforms stored in the indexed memories.

1. The POSITION controls define the position of the traces on the screen and provide ± 4.25 divisions of adjustment. Press the key marked HOME(VAR) to enable variable position (it is enabled when the lamp is off). Try varying the position of the traces, note that whereas OFFSET only affects the waveform when digitising is taking place, POSITION affects it at all times whether RUN/HOLD is at RUN or HOLD. Press the key again to "home" the trace position.

2. The GAIN VARIABLE controls can reduce the amplitude of each trace by any factor between one (fully clockwise) and five (fully anti-clockwise). Press the CAL(UNCAL) key to enable variable gain (it is enabled when the lamp is off). Try varying the gain and note that, because it is within the trace control section, it operates on the waveform after it has been digitised and continues to operate even when the waveform is "held". Press the key again to return to calibrated gain.

3. Each trace is turned off by simultaneously pressing the keys marked CH1 (or CH2) and RCL(NN). Try turning a trace off (note that the CH key should be pressed first to avoid setting RUN/HOLD to HOLD). To turn the trace back on press the CH1 (or CH2) key. Do not try using the RCL(NN) or SAVE(NN) keys at this stage.

4. Trace B has a key marked INV (Invert). Press this key and note that the trace becomes inverted. Press it again to turn inversion off.

5. Trace A has a key marked ADD B. Press this key and note that Trace A then displays the sum of the Trace A waveform and the Trace B waveform. Note that this can also be used for subtraction when Trace B is set to invert. Note also that because add and invert are trace controls they can still be used when either or both channels are "held".

Setting the Timebase

(Start with the DSA reset and the generator set to SINE, 20kHz, 5V pk-pk.)

The timebase is adjustable between 50ns/div and 200mins/div. The timebase speed is set using the two TIME/DIV keys which autorepeat if held depressed. Setting the timebase speed also sets the DSA into one of three modes of operation:

1. Normal Mode

1a. Turn off CH2 and Trace B. Try changing the generator frequency up and down and changing the timebase speed to maintain a roughly constant period on the screen (within the range 5us/div to 100ms/div). This is the "normal" mode of operation whereby the display is updated each time 40.96 divisions of the waveform have been digitised. Note that at low timebase speeds the display update rate becomes slower, this is because of the increased digitising time (at 100ms/div digitising takes 4.096 seconds).

1b. Now set a generator frequency of 100Hz and a timebase speed of 5ms/div. Increase the generator frequency to 1kHz, note that the waveform is starting to become difficult to view. Increase to 2kHz, note that the waveform can no longer be interpreted as a sine waveform and appears to have random patterns superimposed onto it. This is visual aliasing (caused by the vertical separation between sample points being much greater than the horizontal separation). Turn on the sweep magnifier of the display oscilloscope to observe that the waveform is roughly sinusoidal but is made up of only 10 samples per cycle.

1c. Now increase the generator frequency to 20kHz and vary it slightly, note that the waveform changes erratically as the generator frequency is changed, and that waveforms with an apparent frequency down to a few Hz can be obtained. This is true aliasing, caused by the sampling frequency being less than twice the signal frequency (the sampling rate equals 100 divided by the time/div, so at 5ms/div the sampling rate is 20kS /s).

Aliasing effects are common to all digital storage instruments. Note that to avoid true aliasing the sampling rate must be greater than twice the signal frequency (time/div = 50/f) and to avoid visual aliasing the rate must be greater than ten times the signal frequency (time/div = 10/f).

1d. The DSA524 incorporates a feature which automatically sets the timebase to avoid aliasing effects and to provide a sensible waveform period on the screen. Turn off the sweep magnifier on the display oscilloscope. Press simultaneously the two keys marked AUTOSET within the timebase section, note that the timebase is automatically set to 20us/div.

1e. Try changing the generator frequency and using AUTOSET, note how it sets the timebase to maintain between 4 and 10 cycles of the waveform across the screen. (AUTOSET can only operate when a trigger signal of 50Hz or above is being generated.)

2. Roll Mode

For timebase speeds of 200ms/div and slower, the DSA enters roll mode (indicated by an audible "beep" and illumination of the ROLL lamp). In roll mode the waveform data is written onto the screen continuously as it is being digitised. This avoids the long delays that would occur if the screen was only updated after digitising was completed.

Set the timebase to 200ms/div and the generator to 2Hz, note how the waveform appears to "roll" across the screen. Try setting slower timebase speeds and lower generator frequencies (DC coupling will be necessary for lower frequencies). Set the timebase as slow as it will go, note that below 500s/div the SEC and mSEC lamps illuminate together to indicate minutes (speeds as low as 200 minutes/div can be set enabling waveform capture over many hours).

3. Repeat Mode

The maximum sampling rate of the DSA524 is 20MS /s (which is obtained at 5us/div). This is the maximum rate that can be used to capture single event signals. However, if the signal is repetitive, repeat mode can be used. This builds the waveform up by repeatedly digitising it, and can provide equivalent sampling rates up to 2GS /s. For timebase speeds of 2us/div and faster the DSA enters repeat mode (indicated by a "beep" and illumination of the RPT lamp).

3a. Set the generator to 200kHz and set the timebase set to 2us/div (or press AUTOSET), note that the waveform is being digitised at an equivalent rate of 50MS /s. Vary the generator frequency slightly and note that the display update rate is slower in repeat mode, and that the first screen update after the signal is changed is invalid (this is because the waveform is built up from multiple digitisations).

3b. Ground the CH1 input and note that updating of the screen ceases and a message "NO TRIGGER" appears on the screen (this is because repeat mode requires a repetitive trigger signal to be able to operate). Un-ground the input and increase the generator frequency. Increase the timebase speed and note that waveforms up to 35MHz can be captured (this is limited by the input amplifier bandwidth of the DSA) using timebase speeds of up to 50ns/div (2GS /s equivalent sampling rate). Note also that the update rate is slowest at the fastest timebase speeds when in repeat mode.

4. Turn on CH2 and Trace B. Note that the repeat mode update rate is slower when both channels are turned on. Set the timebase speed down to 20us/div noting that when both channels are on, the ALT lamp illuminates for speeds of 10us/div and faster, and that the CHOP lamp illuminates for speeds of 20us/div and slower. CHOP indicates that both input channels are digitised together (on opposite cycles of the sampling clock) while ALT indicates that the input channels are digitised alternately (CH2 followed by CH1). Thus if digitising is un-triggered, or if the input signals do not have a constant relationship to the trigger signal, phase relationships between the signals will not be maintained above 20us/div.

Triggering

(Start with the DSA reset and the generator set to SINE, 20kHz, 5V pk-pk.)

The trigger controls for the DSA524 are broadly similar to those on a conventional oscilloscope. The exceptions are EVENTS DLY and TIME DLY.

1. SOURCE The source of the trigger signal can be CH1, CH2, or EXT (external via the BNC socket below the trigger controls). Note that only AC coupling is available via the external input.

2. MODE The mode switch has three positions, AUTO, NORM, and LINE. AUTO mode is similar to Bright-Line Auto on a conventional oscilloscope. Digitising is performed in synchronism with the trigger signal but, if the trigger signal ceases or the trigger repetition rate falls below 20Hz, digitising continues but without synchronism. In NORM (normal) mode, digitising stops if the trigger signal ceases. In LINE mode, digitising is performed in synchronism with AC line (50 or 60 Hz).

   Try removing the trigger signal by setting SOURCE to external, note that digitising continues (without synchronism) in AUTO mode, but ceases in NORM mode.

2. LEVEL, SLOPE and COUPL (coupling) The function of these controls should be self explanatory. To enable variable trigger level, press the key marked ZERO(VAR I (variable level is enabled when the lamp is off). Try using all of the trigger controls, then return them to their original settings.

PART TWO — MORE ADVANCED FUNCTIONS

The functions covered in the first part of the tutorial enable the user to operate the DSA524 as a basic digital storage oscilloscope. This second part covers the more advanced features which would not be found on a basic DSO.

More about Triggering

(Start with the DSA reset and the generator set to SINE, 20kHz, 5V pk-pk.)

1. TIME DLY (time delay) With TIME DLY off, digitising starts immediately following a trigger. Thus the left-hand edge of the trace shows the waveform immediately after the trigger point. TIME DLY shifts the point at which digitising starts to allow the trace to show the waveform either before the trigger (pre trigger delay) or after the trigger (post trigger delay).

   Set the generator to 5kHz; the trace should now show about one cycle of the waveform starting at the trigger point. Press the TIME DLY (minus) key, note that the message "TIME DLY = +0000 DIV" is displayed. Press the key again to decrement the number to —0001 (note that the keys only increment or decrement when the message is being displayed, on the first press they merely cause the current delay value to be shown).

   The trace should now start one division before the trigger point. Try incrementing and decrementing the delay using the + and — keys, note that the trace can be positioned anywhere relative to the trigger point (in steps of one division) and that the PRE and POST lamps illuminate for negative and positive delays respectively.

   The maximum pre trigger delay is —40 divs and the maximum post trigger delay is + 9999 divs. Note that the + and — keys autorepeat if held depressed, and that the delay can be set back to zero at any time by

pressing both keys simultaneously.

Post trigger time delay can be used to expand a small section of a waveform (as in a sweep-delay oscilloscope). Set a delay of +0002 so that the peak of the sinewave is within the first division of the screen. Now increase the timebase to 5usec/div, note that the delay is increased to +0008 divs so as to maintain a constant time delay thus keeping the sinewave peak within the trace area.

Note that time delay is not available in RPT mode, and that only post trigger time delay is available in ROLL mode. Time delay is automatically set to zero whenever the timebase is set into RPT or ROLL.

2. EVENTS DLY (events delay) This function enables the triggering of the digitising to be delayed by up to 15 trigger events. See the reference section of the manual for a full explanation.

More about Roll Mode

(Start with the DSA reset and the generator set to SINE, 20kHz, 5V pk-pk.)

Because in roll mode the waveform data is written continuously onto the display, it is not necessary to continually stop and restart the digitising process. Consequently when RUN/HOLD is set to RUN, digitising takes place continuously and triggering is disabled.

The purpose of triggering is to enable a specific part of a waveform to be captured. In normal modes the digitising period is always 40 divisions, so defining the trigger point automatically defines the part of the waveform that will be captured. In roll mode the digitising period is not limited to 40 divisions but continues indefinitely.

There are two possible ways in which a triggered roll mode can be provided. The trigger could start the roll which could then continue for 40 divisions, but this would have the disadvantage that pre-trigger data could not be captured. Alternatively, the roll could run continuously until stopped by the trigger, this is the system employed in the DSA524 when SINGLE is used.

1. Set the generator frequency to 2Hz and the DSA timebase to 200ms/div. Select DC input coupling.
2. Set RUN /HOLD to HOLD, ensure that the trigger mode is AUTO and that TIME DLY is off. Now press SINGLE, note that although the roll starts, it stops again immediately. This is because in AUTO mode triggering occurs automatically after a very short delay.
3. Now set TIME DLY to +0005 divisions. Press SINGLE and note that the roll stops after 5 divisions of data has been captured.
4. Set TIME DLY back to zero and set the trigger mode to NORM. Press SINGLE and note that a small section of the waveform prior to the trigger level point has been captured. Thus the waveform occurring between SINGLE being pressed and the trigger occurring has been captured.

Note that in roll mode SINGLE, all the data in the digitising memory is pre-trigger data unless some post-trigger time delay has been set. Pre-trigger time delay is therefore not needed and is disabled.

Similarly, when in roll mode the display always shows the last section of the digitising memory rather than the first. Therefore when SEARCH mode is selected, the SCAN window is initially set fully right instead of fully left.

Memory Search

(Start with the DSA reset and the generator set to SINE, 20kHz, 5V pk-pk.)

Although the screen shows only 1024 words (10.24 divisions) for each trace, the digitising memory captures 4096 words (40.96 divisions) per channel. The SEARCH key enables the whole of the digitising memory to be accessed. It also provides digital magnification by ten (using linear interpolation).

1. Press SEARCH once, the COMP (compress) lamp will illuminate and a filled bar will appear at the top of the screen for 3 seconds (the filled bar represents the 4K of the memory). Note that the waveform is compressed by a factor of four, thus allowing the whole of the digitising memory to be displayed (this is achieved by displaying every fourth word).
2. Press SEARCH again, the SCAN lamp will illuminate and a bar will appear at the top of the screen with the first quarter filled (this bar represents the 4K of the memory and the filled section represents the 1K which is being displayed). Note that the waveform returns to normal and that the bar disappears after 3 seconds.

   Press the key marked SCAN /MAG which has a right-hand arrow, note that the bar reappears. Press the key again, note that the waveform appears to r 'love to the left by one division and that the filled section of the bar moves to the right. The filled section can be regarded as the "scan window" which shows which 1K section of the 4K memory is being displayed.

   Try moving the scan window backwards and forwards using the two arrow keys. Note that the keys only move the window whilst the bar is being displayed, otherwise the first press merely brings up the bar in order to show the present position.

3. Press SEARCH again, the MAG light will illuminate and a bar will appear with the first one tenth filled (the bar represents the present position of the scan window and the filled section represents the 102 words which are being magnified to fill the screen, this can be regarded as the magnify window). Note that the waveform becomes magnified by x10 and that the bar disappears after 3 seconds.

   Try moving the magnify window backwards and forwards using the two arrow keys. Note that this works in just the same way as with the scan window.
4. Press SEARCH several times and note how it cycles through the COMP, SCAN and MAG functions. Press the two SCAN /MAG keys simultaneously in order to turn search off.

Display Update Rate

(Start with the DSA reset and the generator set to SINE, 20kHz, 5V pk-pk.)

The rate at which digitising is repeated and the display is updated can be varied using the key marked RATE. When the rate is set to normal (SLOW and FAST lamps both off) there is a delay of about 0.3 seconds before digitising is restarted when in RUN mode. This delay can be increased to about 3 seconds or reduced to about 0.03 seconds.

The RATE key only operates with timebase speeds between 100ms/div and 5us/div, it has no effect in ROLL or RPT modes.

1. Press the RATE key (the SLOW lamp will illuminate) and vary the generator output. Note that the screen is updated only about once every 3 seconds instead of about 3 times per second. This gives enough time for each digitising to be observed and for the display to be "held" before the waveform is lost and replaced with a new one. Press RATE again to return to normal update rate.
2. Press the RATE key and hold it depressed for 2 seconds (the FAST lamp will be illuminated) and vary the generator output. Note that the screen is updated very quickly providing a near instant response to waveform changes similar to a conventional oscilloscope. Press RATE again to return to normal update rate.

Selecting FAST update cancels any waveform processing functions that have been selected including GAIN VARIABLE, ADD B, INV, RUN AVERAGE and SEARCH.

Indexed Waveform Memories

(Start with the DSA reset and the generator set to SINE, 20kHz, 5V pk-pk.)

The DSA524 has 16 non-volatile indexed waveform memories. These memories are each 1K words in size and are used to save and recall waveforms from Trace A or Trace B.

1. Press the SAVE(NN) key on Trace A, note that the ENTER lamp flashes within the numeric keypad section. Press key 0 followed by key 1, this stores the waveform currently displayed on Trace A into memory 01. Note that the screen shows "MEMORY 01 = TRACE A" and that RUN /HOLD is set automatically to HOLD.
2. Now press RCL(NN) on Trace B, followed by key 0, followed by key 1, this recalls the waveform onto Trace B. Note that the screen shows "TRACE B = MEMORY 01" and that the MEM lamp (in the Trace B area) illuminates in place of the CH2 lamp.
3. Set RUN /HOLD back to RUN, and change the generator frequency. Note that Trace B is now displaying a reference waveform which can be used for on-screen comparison with the CH1 signal. Operate the Trace B invert and gain variable functions, note that these operate on a recalled waveform just as they do on a waveform sourced from an input channel.
4. Press the Trace B RCL(NN) key twice and note that "TRACE B = MEMORY 01" is displayed again, allowing the user to check which memory is being displayed at any time. Press the CH2 key on Trace B to return to a display of CH2.

The 16 memories are numbered 01 through to 16. They can only be used to store the contents of a trace memory (i.e. a waveform displayed on the screen). Recalled waveforms are not affected by the SEARCH function.

Cursor Measurement

(Start with the DSA reset and the generator set to SINE, 20kHz, 5V pk-pk.)

The DSA524 incorporates cursor measurement with on-screen digital readout of voltage and time difference. Cursor measurement can only be performed in HOLD, and on only one channel at a time. The cursor line starts at the left hand edge of the screen and intersects with the waveform at the reference cursor point. It is then shifted upwards away from the trace, continues sideways and then comes down to intersect with the waveform again at the delta cursor point before continuing to the right hand edge of the screen. The measurement is made between the two cursor points.

1. Press CURS ON/OFF (key 4), Trace B will turn off and a flashing cursor line will be displayed. Note that RUN/ HOLD is set to HOLD and that the screen shows the message "Delta A = XX.XV XXX.XuS" representing the voltage difference and time difference between the two points.
2. Try moving each of the cursors using the arrow keys marked REF CURS and A CURS. Note that the cursor points "track" the waveform automatically and that the cursor movement speeds up when the keys are held depressed.
3. Press CURS A/ B (key 5), Trace A will be replaced with Trace B. Note that the cursor points adjust automatically to the new waveform. Press CURS ON/OFF again to turn cursor measurement off.

Averaging

(Start with the DSA reset and the generator set to SINE, 20kHz, 5V pk-pk.)

The DSA524 can average any number of readings from 2 up to 255, enabling large improvements to be made to the signal to noise ratio of noisy signals. The average number is initially set to 16.

1. Turn off Trace B and note the waveform amplitude on Trace A. Then remove the trigger signal by setting the source to EXT. The waveform should now be unsynchronized, this simulates random noise because the phase of the signal is now random.
2. Press the RUN AVERAGE key (within the timebase section), the indicator lamp will illuminate to show that averaging has been selected. The screen will show the message "AVERAGE COUNT = X" where X increments continuously between 001 and 016. Note that the trace is updated each time the message reaches 016 and that the signal amplitude has been reduced, typically by a factor of four (truly random noise is attenuated by the square root of the number averaged). Set the DSA to HOLD and press SINGLE, note that averaging is performed once only.
3. Now press SHIFT (key 8) followed by SET AVG (key 4), the message "AVERAGES = 016" will be displayed showing the current setting. Now try using the REF CURS arrow keys to increment or decrement the number. Set it to 064 and press ESCAPE to terminate set-average mode. Re-start averaging, note that the signal amplitude is now reduced typically by a factor of eight instead of four. Use SET AVG again to set the averages back to 16.

   The above mode of operation is known as a totalising average because the screen is only updated when the total number of digitisings have been averaged. An alternative mode is a running average whereby the screen is updated each time digitising takes place.
4. Return the trigger source to CH1. Press RATE, the SLOW lamp will illuminate. When SLOW and RUN AVERAGE are both illuminated the mode is set to running average. Press SINGLE, note that the screen is updated with the new average value on every count. Note that averaging can be stopped at any time by pressing RUN/HOLD.

   Averaging is not available in ROLL mode and only a totalising average is available in RPT mode. In RPT mode the average number is only displayed each time averaging is completed.

Dot Joining and Interpolation

(Start with the DSA reset and the generator set to SINE, 20kHz, 5V pk-pk.)

The DSA524 is initialised to use analog dot joining. This links the 1024 individual sample points on the screen with angled lines to simulate one continuous line. This gives a display which is easy to view, and reduces the number of samples per cycle required to avoid visual aliasing.

However, when the vertical separation between adjacent sample points is large, dot joining can reduce the peak amplitude of the waveform. To avoid this a "dots" display can be selected instead of a "line" display. A dots display also has the advantage that the exact position and level of each sample point can be viewed.

1. Set the generator to SINE, 20kHz (with the DSA at 20us/div) and turn on sweep magnify on the display oscilloscope. Press SHIFT followed by DOTS (key 7), note that the individual sample points are now visible.
2. Turn off the sweep magnifier and note that the display shows some visual aliasing. Return to a "line" display by pressing LINE (key 7), note that the visual aliasing is reduced.

The sweep magnifier of the display oscilloscope provides an analog expansion of the trace. The magnify function on the DSA (via the SEARCH key) provides a digital expansion. 102 words of the digitising memory are used to fill the 1024 words of the trace by using linear interpolation to generate nine extra words between each pair.

When a waveform has been captured at a very low number of samples per cycle, MAG can be used to observe it. If the waveform is sinusoidal in nature, linear interpolation will not reproduce the waveform shape very well if the number of samples per cycle is less than ten. The DSA524 provides the alternative of sine interpolation which provides a good reconstruction of a sinewave from only four samples per cycle by using a mathematical curve fitting algorithm.

3. Reduce the timebase speed to 100us/div, this reduces the number of samples per cycle to five. Press SEARCH three times to select MAG mode, note that the displayed waveform shape is poor. Press the SINE INTERP key, the lamp will illuminate, note that the displayed waveform shape is greatly improved.

Trace Multiply

(Start with the DSA reset and the generator set to SINE, 20kHz, 5V pk-pk.)

The trace multiply function (A = AxB) allows the product of two waveforms to be displayed. Thus, for example, if Trace A was displaying a voltage waveform and Trace B was displaying a corresponding current waveform, trace multiply could be used to display the power waveform on Trace A.

1. Note the waveforms obtained on each trace then press SHIFT followed by A = AxB (key 2), RUN/HOLD will be set to HOLD, note that the multiplied waveform appears on Trace A.
2. Note that trace multiply cannot be used while digitising is taking place (pressing RUN or SINGLE will cancel the function). Note also that ADD B and GAIN VARIABLE on Trace A are disabled after trace multiply has been selected. Press ESCAPE to return Trace A to its normal display.

The multiplied waveform is scaled using units of one screen division with the centre of the screen being zero. The traces are multiplied exactly as they appeared on the oscilloscope display including offsets introduced by the trace position controls. Thus at a point where the position of Trace A is +2 divs and of Trace B is -1.5 divs, the value of the multiplied waveform will be -3 divs.

It should be noted that if either trace has values greater than ±1 divs then overflows could occur on the multiplied waveform. The displayed waveform is limited to ±4.25 divisions and consequently -3 divs multiplied by -2.5 divs will be displayed as +4.25 divs instead of +7.5 divs.

4. Use the Trace A and Trace B variable controls to alter the amplitude and position of the waveforms prior to multiplication. Note the results. Press ESCAPE to exit.

Program Mode

(Start with the DSA reset and the generator set to SINE, 20kHz, 5V pk-pk.)

The DSA524 can operate as a fully programmable instrument. It can "learn" individual or sequential front panel settings, store them in non-volatile memory, and "replay" them on demand. Up to 50 settings can be stored.

Each front panel setting includes the state of every key and rotary control and the source of each trace waveform. Thus if a setting is "learned" which includes a trace recalled from a waveform store, that same store will be recalled again when the setting is "re-played". Thus reference waveforms can be recalled automatically within PROGRAM mode.

1 Select "learn" mode by pressing LEARN (the LEARN lamp will illuminate). Note that the screen shows the message "NEXT POSITION = 01".

2. Press SET(NN), followed by key 3, followed by key 0 (for 'example). The screen will show the message "STORED IN MEM = 30" followed by "NEXT POSITION = 31", showing that the current front panel settings have been stored in memory position 30.

3. Now reset the front panel including time/div, volts/div, input coupling, rotary controls etc. Press SET/NEXT, the screen will show "STORED IN MEM = 31" followed by "NEXT POSITION = 32". Now recall waveform memory 01 onto Trace B and then press SET/NEXT again. Further sets of front panel settings have now been stored in positions 31 and 32.

4. Exit "learn" mode by pressing the LEARN and REPLAY keys simultaneously, and select "replay" mode by pressing REPLAY (the R PLY lamp will illuminate). The screen will show "NEXT POSITION = 33", showing that the most recently used position was 32.

5. Press SET(NN) 30, the front panel will reset and the screen will show "REPLAYED MEM = 30" followed by "NEXT POSITION = 31". Press SET/NEXT, the front panel will be reset again. Press SET/NEXT again, the front panel will be reset and the waveform in memory 01 will appear on Trace B.

6. Press SET(NN) 30 to reset the front panel to its original settings and exit "replay" mode by pressing the LEARN and REPLAY keys simultaneously.

Hardcopy Output

The DSA524 can provide hardcopy output via dot matrix printer (Epson codes compatible, with a serial interface), a digital X-Y plotter (HP-GL codes compatible, with a serial interface), an analog X-Y plotter, or an analog Y-T chart recorder.

Because different users will wish to use different types of printers or plotters, this subject cannot be usefully covered in this tutorial. Please refer to the reference section of the manual for a description of the PRINT and PLOT functions.

Remote Interfacing

The RS-423 serial interface (RS-232 compatible) and the optional IEEE-488 interface of the DSA524 enable it to be connected to a wide variety of other equipment. The interfaces can be used for full remote control of the DSA (anything that can be controlled from the keyboard can also be controlled via the interfaces), and for bi-directional transfer of waveform data.

Refer to the reference section and appendices for full details.

A Final Word

This tutorial has covered most of the functions of the DSA524 in terms of its use with a display oscilloscope. The DSA524 is a highly sophisticated and versatile instrument which has many further uses which have not been touched upon in the tutorial, in particular its use as an interfaceable and programmable instrument. Some of its other facilities are covered in the reference section of the manual, the appendices, or in individual application notes.

APPENDICES

APPENDIX A. THE OSCILLOSCOPE DISPLAY

Single or dual cable connection

The DSA524 produces a multiplexed output which enables two traces plus text to be displayed using only one channel of the display oscilloscope. The multiplexed output also incorporates a trigger signal. Consequently the DSA can be connected to the oscilloscope via just one cable with triggering being sourced from the input channel.

The disadvantage of single cable connection is that the trigger signal is visible at the left hand edge of the screen as a very narrow vertical pulse followed by a short bright line. Connecting a second cable from the "Trig out" socket to the external trigger input of the oscilloscope and setting the scope to external trigger removes the visible trigger signal from the screen.

Triggering

Because the DSA524 produces a multiplexed output waveform, trigger adjustment is very important particularly when text is being displayed. If a satisfactory initial set-up display cannot be obtained check the following points:

The 'scope must be set to single channel operation. The input coupling must be DC and the sensitivity must be set to 100mV/div. The sweep hold-off and trigger delay (if present) must be set to minimum. The sweep speed must be set to 50us/div. The trigger source must be from the input channel (not vertical mode). The trigger slope and level must both be negative.

Adjust the trigger level. If a satisfactory display can still not be obtained try setting the sweep speed to 20us/div and then slowing it down to 50us/div using the sweep variable control.

When using a single cable connection, some oscilloscopes (those having a poor dynamic range on their trigger circuit) may give unstable triggering when full screen height waveforms are being displayed. Should this occur, first try careful adjustment of the trigger level control but if the trouble persists change to a two cable connection.

Vertical Size

The amplitude of the vertical output is factory adjusted to an accuracy of + 1 %. The two horizontal lines of the set-up display are intended to be exactly 6 divisions apart. The output level can be adjusted to compensate for inaccuracies of the oscilloscope using the rear panel preset adjustment marked "Set Height". If the linearity of the oscilloscope is poor, however, it may not be possible to set the two lines at exactly ±3 divisions from the arrow tip. If so ignore the vertical position of the arrow tip and set the two lines to be at ±3 divisions from the graticule centre line.

The horizontal timing of the DSA524 is crystal controlled to an accuracy of 0.01% (except for "repeat" mode operation) and cannot be adjusted.

APPENDIX B. ALIASING

One problem that occurs with digital storage oscilloscopes that does not occur with real-time oscilloscopes is aliasing.

Sampling theory dictates that any periodic waveform must be sampled at more than twice the highest frequency component to avoid aliasing. Aliasing causes the apparent waveform frequency to be much lower than the real frequency. Thus if the timebase is set too low an invalid display will result (see Fig a).

To avoid aliasing the timebase must be set as follows:

Minimum time/div = 50 divided by the maximum cyclic signal frequency.

The difficulties occur when the signal frequency is unknown. In this case it is safest to set a fast timebase speed initially and work down.

A second form of aliasing that can occur is visual aliasing. This occurs when the display is made up of bright dots and the number of samples per waveform period is low (though greater than two). The eye can be deceived into incorrectly linking the dots to form a slower period waveform (see Fig b). The dot join feature of the DSA524 greatly reduces the chances of visual aliasing occurring.

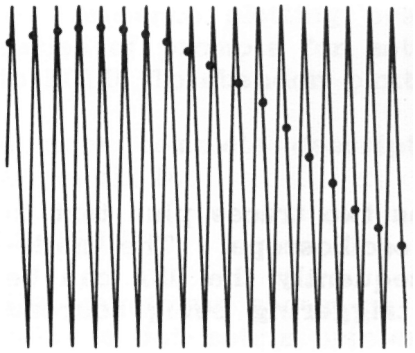


Fig a. True aliasing - waveform sampled at less than twice the signal frequency (in this case approximately at the signal frequency).

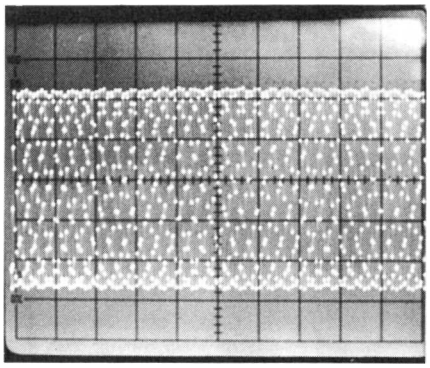


Fig b Visual aliasing - vertical separation between samples large in comparison to horizontal separation, leading to incorrect interpretation by the eye.

If the input signal is repetitive and the trigger repetition rate is between 50Hz and 5MHz the AUTOSET function of the DSA524 can be used. Autoset resets the timebase to a speed suited to the trigger rate and well above the point at which aliasing effects can occur.

APPENDIX C. SINGLE-SHOT BANDWIDTH AND INTERPOLATION

Probably the most important use of a digital storage instrument is for the capture of single-shot waveforms (i.e. waveforms which occur only once). The user will need to understand the bandwidth restrictions which apply to this mode of operation.

Nyquist sampling theory dictates that a waveform can be perfectly re-constructed if sampled at more than twice the frequency of the highest frequency component. Thus a 9.9 MHz sinewave could be reconstructed if sampled at 20MHz. Unfortunately this assumes that sampling can take place for an infinite period of time. Clearly this is not possible with a single-shot waveform.

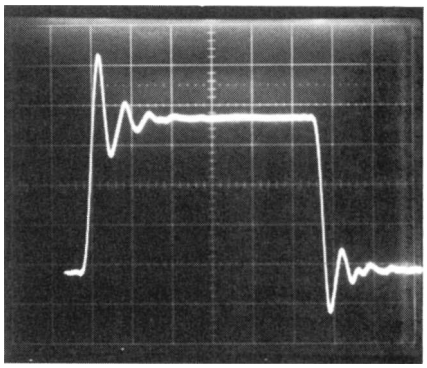
In theory a single-shot waveform can only be perfectly reconstructed using an infinite sampling frequency. This is because the waveform has discontinuities at the start and end which give rise to infinite frequency elements. Given a known maximum sampling frequency we need to know how good a representation of the original waveform can be achieved.

Because there can be no certainty of the existence of any cyclic elements in a single-shot waveform, sampling theory must be abandoned. Instead, a subjective principle must be used to decide what constitutes an acceptable representation of a waveform. This will depend on the information that the user needs to obtain from the waveform.

Consider the waveform of Fig c which consists of a rapid change of level, followed by an exponential decay of sinusoidal oscillations. If the user requires only to know the settled amplitudes before and after the change of level the sampling frequency requirements are modest since a representation which merely indicates the disturbance and the settled values will suffice.

However, if the user requires to know the rate of change of the rising edge, the sampling frequency requirements are considerable since a number of samples must be taken during the time of the rise.

Fig c.



Most commonly, the user merely requires a representation of the general shape of the waveform. In the case of the waveform of Fig c it is clear that a reasonable representation can be obtained using ten samples per cycle of the sinusoidal frequency. This leads to a useful rule of thumb which is that the sampling frequency should be at least ten times that of the fastest cyclic element in the waveform. Alternatively we could say that the single-shot bandwidth equals one tenth of the maximum sampling frequency.

Because a cyclic element which is represented by ten samples occupies only 0.1 divisions on the display, it will be necessary to use "magnify" mode to view it properly. When the DSA524 display mode is set to MAG it not only increases the spacing between the original samples by ten, but also calculates and displays intermediate samples using mathematical interpolation.

The standard interpolation provided by the DSA524 is linear. Linear interpolation joins the true samples with straight lines, which improves the visual appearance of the waveforms when the number of samples per cycle is low. Linear interpolation provides a good reconstruction of waveforms which are made up mainly of linear elements.

The DSA524 also provides sine interpolation as an alternative. This is based on a mathematical curve fitting algorithm known as the "cubic spline", and provides an excellent reconstruction of waveforms which appear to be made up of simple sinusoids. Sine interpolation will provide a near perfect reconstruction of a sinewave sampled at only four samples per cycle.

This leads to a second useful rule of thumb which is that, when using sine interpolation, the single-shot bandwidth equals one quarter of the maximum sampling frequency.

Sine interpolation will not provide a good reconstruction of the parts of a waveform which are not smooth curves. It should therefore not be used with pulse, triangle, sawtooth waveforms etc.

APPENDIX D. ANALOG PLOTTER "PLOT" FUNCTION

The waveforms shown on the oscilloscope display can be sent either to an analog X-Y plotter or to a Y-T chart recorder using the analog plotter interface.

The DSA is factory initialised for use with a digital plotter. To change over to use with an analog plotter key in "function 26" (press FUNCTION NN, followed by 2 followed by 6). To return to use with a digital plotter key in "function 27".

The analog plotter interface is mounted on the rear panel and has five 4mm sockets marked X, YA, GND, YB, and PL (pen lift). The X signal is only required when using an X-Y plotter. When using a chart recorder the pen lift signal can be used to control the chart movement.

The waveforms for Trace A and Trace B are sent simultaneously to their separate output sockets along with an X axis signal for use with X-Y plotters. The 10.24 divisions of the display are plotted using a level of 100mV/div (for both Y and X) at a rate selectable as 1,2,5 or 10 seconds per division. The pen-lift signal is normally "low to lift" but can be inverted.

To set the plot rate, press SHIFT (key 8) followed by SET PLOT (key 5). The oscilloscope display will show the present plot rate. Press one of the REF CURS keys (key 2 or 3) to select a new

value, then press ESCAPE. If the DSA is not connected to an oscilloscope the plot rate may be set directly using the FUNCTION NN key (see Section R27.).

Two versions of the PLOT function are provided. The default version provides prompts for manual or semi-automatic operation of the recorder or plotter. Its operation is as follows:

Before the PLOT function is commenced, the Y and X output signals will both be at zero, representing the bottom left-hand corner of the oscilloscope display. The pen lift signal will be set to "up".

Press PLOT (key 6), the oscilloscope display will show "ZERO PEN/HIT ANY KEY". If RUN/HOLD was set to RUN it will become set to HOLD. The interface will output YA and YB values equivalent to + 4.25 divisions, and an X value equivalent to +0.12 divisions. This represents the left-hand centre of the oscilloscope graticule. Adjust the zero controls of the plotter/recorder accordingly. The pen lift signal will remain set to "up".

Press any key (e.g. PLOT), the display will show "PEN DOWN/ HIT ANY KEY". The pen lift signal will be set to "down". If automatic pen lift control is not being used, lower the pen.

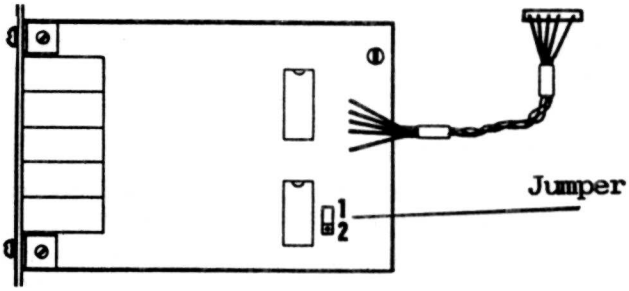
Press any key, the display will show "PLOTTING". Plotting will commence starting at X position 0.00 and continue to position 10.24. When plotting has finished the display will show "PEN UP/HIT ANY KEY". The pen lift signal will be set to "up". If automatic pen lift control is not being used, raise the pen.

Press any key, the Y and X output signals will both be set to zero and the pen lift signal will remain "up". To abandon the PLOT function at any stage before it is completed press ESCAPE.

The alternative version of the PLOT function is intended for fully automatic control of the recorder/plotter. To change to this version, key in "function 25". To return to the normal prompted version, key in "function 26". The operation of the alternative version is as follows:

Press PLOT (key 6), the pen lift signal will be set to "down", and plotting will commence starting at X position 0.00 and finishing at 10.24. If RUN/HOLD was set to RUN it will become set to HOLD. When plotting is completed, the pen lift signal will be set to "up", and the Y and X output signals will both be set to zero. To abandon plotting at any time press ESCAPE.

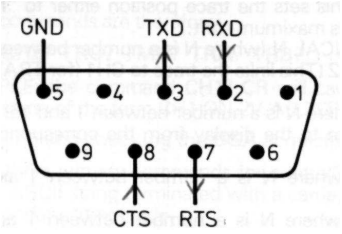
The Pen Lift signal has a level of either 0 volts or 5 volts from a source impedance of 1K ohm. The default polarity of this signal is "low to lift". This can be changed to "high to lift" by dismantling the case and changing the jumper on the analog plotter interface PCB from position 1 to position 2 (see diagram below).



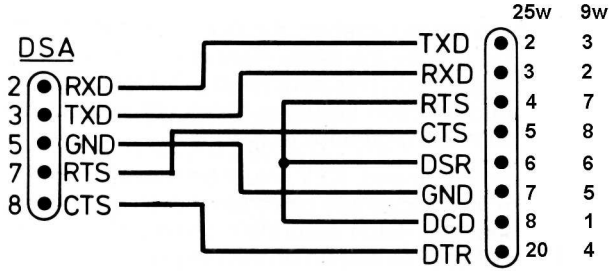
The signal can be used to switch most logic based control inputs including TTL. However it should not be connected to input circuits which sink currents to below 0 volts or which source currents of more than 1mA to a voltage above 5 volts. Doing so could cause incorrect operation of the whole plotter interface.

APPENDIX E. CONNECTING TO THE SERIAL INTERFACE

The interface uses a female 9-pin D connector and has five active connections: pin 2 (RXD) is the data input line, pin (TXD) is the data output line, pin 5 is signal ground, pin 8 (CTS) is the hardware handshake input, pin 7 (RTS) is the hardware handshake output. RTS can be disabled and forced permanently high by using FUNCTION 83 on the DSA, it can be re-enabled by using FUNCTION 82.



Unfortunately, although there are connection standards for modems and for terminals, there is no single connection standard applying to other equipment fitted with an RS-232C interface. It will therefore be necessary to refer to the technical handbook of the equipment concerned before a suitable connection cable can be made up. The most commonly used connector system is a 25 pin "D" connector in a "terminal" configuration, and a suitable cable wiring scheme for this is shown below.



Where bi-directional transfer of data is required, the TXD of the DSA should be connected to the RXD of the other equipment and the RXD of the DSA should be connected to the TXD of the other equipment. Where unidirectional data transfer is required (i.e. when connecting to a printer or plotter), the RXD of the DSA can be left unconnected (unless X-ON/X-OFF handshaking is used).

Unless the baud rate is set very low, some form of handshaking connection will probably be necessary. If hardware handshaking is not being used, pin 8 (CTS) on the DSA cannot be left unconnected and must be taken permanently high. This can be done by connecting pin 8 to pin 7 (RTS) and using FUNCTION 83 to force RTS permanently high. RTS can be re-enabled for normal handshaking operation using FUNCTION 82.

Handshaking is necessary when the receiving equipment cannot accept the data as fast as the sending device is sending it. Handshaking allows the receiving device to tell the sending device when to send data and when not to send data, thus controlling the effective rate at which data is transmitted.

Handshaking is not always needed. The receiving equipment may be able to keep up with the incoming data without needed to interrupt it, either because the baud rate is set low enough that it can act on the data as fast as it is being sent, or because it has a large enough data-input buffer to accept all of the transmitted data in one stream. However, even when a large data buffer is available, handshaking can sometimes still be needed at high baud rates because the RS-232 hardware of the equipment cannot transfer data bytes into the buffer fast enough.

The DSA has a 40 byte data input buffer. When transmitting data to the DSA baud rates up to 9600 can be used without handshaking, above this handshaking will be needed for strings in excess of 40 characters.

When making connection to a printer or plotter, the need for handshaking will depend upon the characteristics of that device. Because the amount of data transmitted is large (approx. 30K bytes for a "print") the baud rate needs to be kept high to minimise transmission time. Since the device is unlikely to have a buffer large enough to accept the data in one stream, handshaking will almost certainly be needed.

There are two basic types of handshaking, hardware handshaking and X-ON/X-OFF handshaking. Both types are provided on the DSA.

Hardware handshaking uses the RTS and CTS lines of the DSA. When the RTS line is set to a 0 (a positive voltage level) the DSA is ready to receive data, when it is set to a 1 (a negative voltage level) the DSA is not ready to receive data. When CTS is pulled to a 0 (positive) the DSA is enabled to send data, when it is pulled to a 1 (negative) the DSA is disabled from sending data.

X-ON/X-OFF handshaking uses the TXD line of the receiving device to send messages to the transmitting device telling it to stop or to start sending data. The X-OFF message (ASCII 13) stops transmission, the X-ON command (ASCII 11) starts transmission.

The protocol of the DSA is fixed (8 data bits, 1 start bit, 1 stop bit, no parity) and therefore any incompatibility must be removed by adjusting the protocol of the other equipment. Most computers have fully adjustable protocol but some printers and plotters do not.

It is not essential to have exactly the same protocols on both interconnected interfaces. The other interface must use 8 data bits and 1 start bit, but parity can be even, odd or none, and stop bits can be 1, 2 or more.

The wide range of baud rates available from the DSA should ensure compatibility with virtually all equipment. Where the other equipment also provides a choice of baud rates there are a number of points to bear in mind when choosing which rate to use.

Some types of equipment cannot handle incoming data at high baud rates even when handshaking is correctly established. Such problems are minimised at lower baud rates but waveform data will take a long time to transfer. High baud rates will give shorter transmission times but may produce problems with missing bytes.

APPENDIX F. SOFTWARE COMMANDS

The RS-423 and IEEE-488 interfaces provide identical facilities for control and data transfer. The commands listed below are common to both interfaces. The DSA is controlled by sending it ASCII strings. Each string must be terminated with a carriage return (shown in examples as CR). All commands are case sensitive.

When the DSA receives a valid command string it responds by sending back the string "OK CR". If the command string is not valid the DSA responds by sending back the string "ERROR N CR" where N is the number of the first apparently invalid byte of the command string.

1. Controlling the DSA front panel set up.

For controlling the front panel, each ASCII string must consist of a primary command followed by a comma followed by one or more secondary commands (separated by commas) followed by a carriage return.

There are seven primary commands for control of the front panel. Each one defines a control area to which the secondary command (or commands) will apply. The primary commands are as follows:-

CH1 This defines the control area as channel 1
CH2 This defines the control area as channel 2
TRG This defines the control area as trigger
TMB This defines the control area as timebase
TRA This defines the control area as trace A
TRB This defines the control area as trace B
KEY This is a Global control command

For **CH1** or **CH2** the secondary commands are as follows:

2mV, 5mV, 10mV, 20mV, 50mV, 100mV, 200mV, 500mV, 1V, 2V, 5V, or 10V (This sets the input sensitivity.)
AC, DC or GND (This sets the input coupling.)
ZERO or VAR,N (where N is a number between -100 and +100) (This sets the offset level equal either to zero or to N% of its maximum value.)
OFF or ON (This turns the channel off or on.)

Example: CH 1,20mV, DC,VAR,50 CR

For **TRG** the secondary commands are as follows:

CH1, CH2 or EXT (This sets the trigger source.)
AUTO, NORM or LINE (This sets the trigger mode.)
POS or NEG (This sets the trigger slope.)
ZERO or VAR,N (where N is a number between -100 and +100) (This sets the trigger level either to zero or to ±N% of its maximum value.)
AC, DC or HFREJ (This sets the trigger coupling.)
EDLY,N (where N is a number between 0 and 15) (This sets the trigger events delay.)
TDLY,N (where N is a number between -40 and 9999) (This sets the trigger time delay.)

Example: TRG,CH2,AC,TDLY, -10 CR

For **TMB** the secondary commands are as follows:

50nS, 100nS, 200nS, or 500nS (This sets the timebase speed in nanoseconds per division).
or 1uS, 2uS, 5uS, 10uS, 20uS, 50uS, 100uS, 200uS, or 500uS (this sets the timebase speed in microseconds per division).
or 1mS, 2mS, 5mS, 10mS, 20mS, 50mS, 100mS, 200mS, or 500mS (this sets the timebase speed in milliseconds per division).
or 1S, 2S, 5S, 10S, 20S, 50S, 100S, 200S or 500S (This sets the timebase speed in seconds per division).
or 10M, 20M, 50M, 100M or 200M (This sets the timebase speed in minutes per division).
COMP (This sets the SEARCH function into Compress mode).
SCAN,N (where N is a decimal number between 0 and 3100) (This sets the SEARCH function into Scan mode with the trace starting at word N).
MAG,N (where N is a decimal number between 0 and 900) (This sets the SEARCH function into Magnify mode with the trace starting at word N).
SROFF (This turns any of the SEARCH modes off).
NORM, SLOW or FAST (This sets the display update rate).
ION or IOFF (This sets sine interpolation on or off).
AON or AOFF (This sets averaging on or off). Example: TMB,10uS,AON,SLOW CR

For **TRA** or **TRB** the secondary commands are as follows:

HOME or VAR,N (where N is a number between -100 and +100) (This sets the trace position either to "home" or to N% of its maximum shift.)
CAL or UNCAL,N (where N is a number between 0 and 100)
CH1 or CH2 (This links the trace to CH1 (for TRA) or CH2 (for TRB).)
RCL,N (where N is a number between 1 and 16) (This recalls a waveform to the display from the corresponding indexed memory.)
SAVE,N (where N is a number between 1 and 16) (This memory.)
SAVE,N 'where N is a number between 1 and 161 (This stores the waveform presently displayed on the trace into the corresponding indexed memory.)
ADD or NOADD (TRCA only) (This turns the "add B to A" function on or off.)
INV or NOINV (TRCB only) (This turns the trace invert function on or off.)

Example: TRA,HOME,UNCAL,40 CR KEY

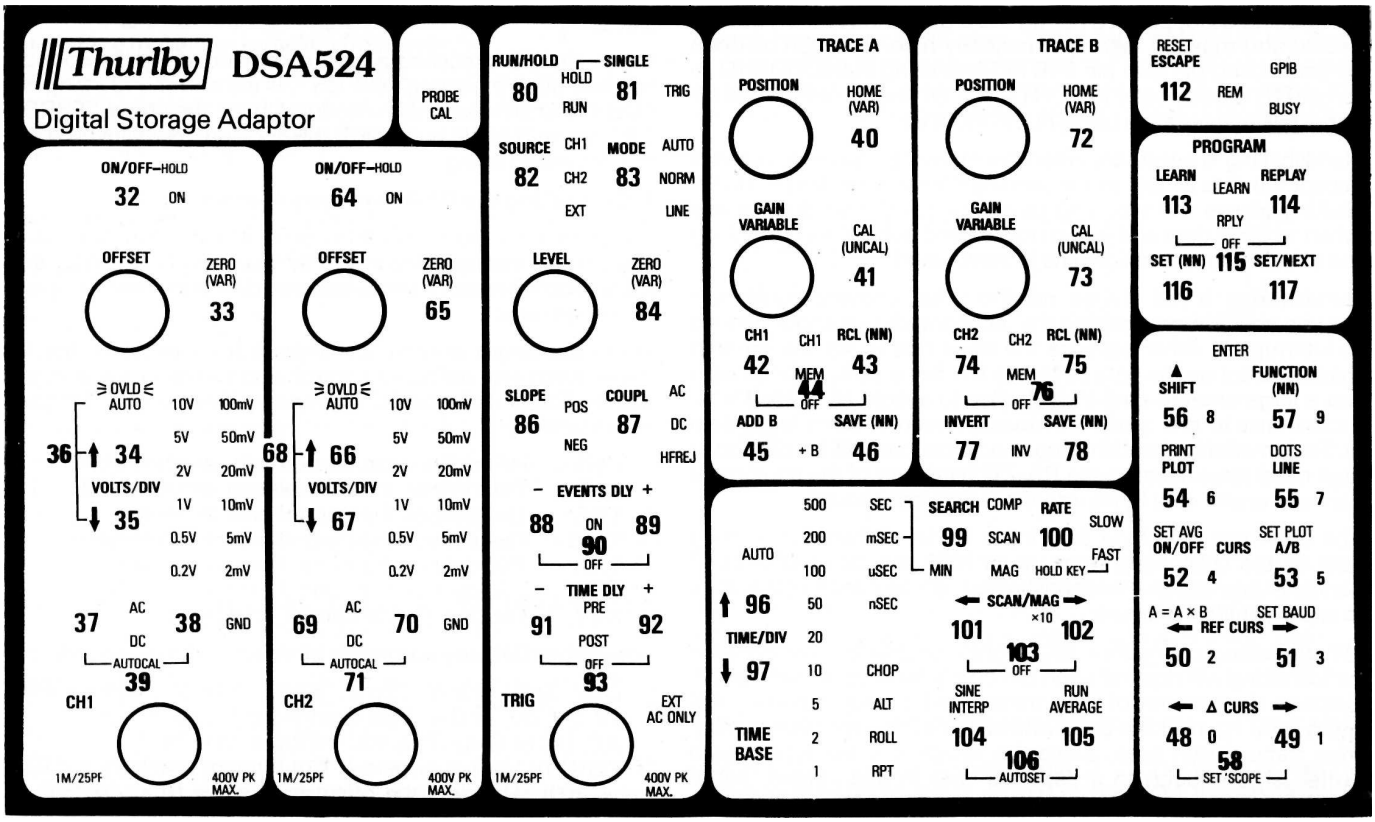
KEY

The KEY command enables the front panel of the DSA to be controlled in exactly the same manner as if the front panel keys were being pressed. This command provides for control of any key operated function including those not covered by the previous six primary commands (e.g. PLOT).

The primary command, KEY, must be followed by one or more (maximum five) secondary commands each of which represents a front panel key. Each secondary command is a two or three digit decimal code as shown on the diagram below.

Example: KEY,34,34,97 CR

This would have the effect of incrementing the CH1 volts/div by two steps and decrementing the timebase time/div by one step.



Note that if the DSA is being used with an oscilloscope display, the set-up display will remain on the screen until a key is pressed or a KEY command is sent. Where immediate use of the display is required the command for ESCAPE (KEY,112) should be sent.

2. Reading back the front panel status

The front panel status can be read by sending the primary command for one of the control areas followed by a question mark (followed by a carriage return).

The valid commands are therefore:

CH1? CH2? TRG? TMB? TRA? TRB?

EXAMPLE: the command CH1? CR will cause the DSA to send a string of the form CH1,ON,2V,AC,ZERO,0000, OK CR.

3. Controlling and checking the DSA acquisition modes

There are three primary commands for controlling acquisitions. Each is an ASCII string terminated with a carriage return. There are no secondary commands.

RUN This sets Run/Hold to Run, enabling continuously repeating acquisitions.

HOLD This sets Run/Hold to Hold, freezing the digitising memories.

SINGL (only when Run/Hold is at Hold) This enables a single acquisition.

EXAMPLE: RUN CR

There is also a command for checking the current acquisition status of the DSA.

BUSY? This causes the DSA to send back a status letter. The letter is H if the DSA is in Hold, or B if the DSA is either in Run or is still completing a Single.

4. Reading waveform data from the DSA

The data from any of the digitising memories, trace memories or indexed memories can be sent over the interfaces. The data can be sent in either binary, hex or decimal. In binary mode each word of the memory is sent as a single byte. In hex and decimal modes the characters are sent in ASCII, two characters per word in hex mode and three characters per word in decimal mode.

The DSA is factory initialised to send in decimal. To change the mode, send the primary command MODE followed by a comma followed by one of the secondary commands BIN, HEX or DEC (followed by a carriage return). Once changed, the new mode is retained in non-volatile memory.

EXAMPLE: MODE,BIN CR

To read the data, send the primary command MEM? followed by a comma followed by one of the secondary commands listed below (followed by a carriage return).

The secondary commands are as follows:

AQU1 or AQU2 This causes 4096 words to be read from the digitising memory of CH 1 or CH2.

TRA or TRB This causes 1024 words to be read from the trace memory of Trace A or Trace B.

TRAB This causes 512 words to be read from each of the trace memories in an interleaved manner (only every alternate word in each memory is read). A total of 1024 words is sent. N (where N is a number between 1 and 16) This causes 1024 words to be read from the corresponding indexed memory.

EXAMPLE: MEM?,7 CR

After the final word has been sent, the DSA will send the string: SPACE OK CR.

5. Loading data into the waveform memories

Data can be loaded into any of the digitising memories, trace memories or indexed memories. The data can be sent in binary, hex or decimal formats. The format is changed using the MODE command (see previous section for an explanation of this command).

To load the data, send the primary command **MEM** followed by a comma followed by one of the secondary commands listed below (followed by a carriage return).

The secondary commands are as follows:

ACQ1 or AQU2 This loads the digitising memory of CH1 or CH2. 4096 words must be sent.

TRA or TRB This loads the trace memory of Trace A or Trace B. 1024 words must be sent.

N (where N is a number from 1 to 16) This loads one of the indexed memories. 1024 words must be sent.

EXAMPLE: MEM,TRA CR

After this command has been sent the DSA will send back the string: READY CR indicating that it is ready to accept the data. When the correct number of bytes have been received it will send back the string: OK CR.

6. Further primary commands

IDENT? This causes the DSA to send back an identity string which includes the firmware level, e.g. DSA524 V2.67

BEEP This causes the audio transducer on the DSA to give a short "beep".

TEXT,STRING where STRING is a string of up to 20 ASCII characters from the set listed below; This causes the string to be displayed on the screen for 3 seconds.

FPOFF This causes the DSA front panel to be disabled. The front panel lamp marked REM (remote) will be illuminated.

FPON This causes the DSA front panel to be enabled again.

Note that FPOFF also disabled the primary command KEY, thus if KEY commands are required when the front panel is disabled it will be necessary to send FPON followed by the appropriate KEY commands followed by FPOFF.

List of allowable ASCII characters for the TEXT command:

All upper case letters A to Z, numbers 0 to 9, plus the following lower case letters and symbols: m, n, u, +, -, *, /, =. In addition, sending the ASCII character ! will produce a delta symbol, [will produce a left facing arrow and] will produce a right facing arrow. Space will produce a space.

7. Saving and restoring the total contents of the DSA memories

The total contents of the non-volatile memories of the DSA (i.e. digitising memories, screen memories, indexed waveform stores, front panel set-up memory, and Program mode memory) can be saved to a remote location (e.g. a disk store) and restored from a remote location using the commands **DUMP?** and **LOAD**.

To save data from the DSA, send the command string DUMP? CR the DSA will send 30,000 bytes of data followed by the string SPACE OK CR. The data will be sent in the format set by the MODE command (see Section 4).

To restore data to the DSA, send the command string LOAD CR the DSA will send back the string READY CR indicating it is ready to accept data. When 30,000 bytes have been received it will send back the string OK CR.

Important note! No modifications must be made to the data saved using the DUMP? command. Also the MODE setting (see Section 4) must be the same when the data is restored as it was when it was saved. To guard against this, any save and restore program should incorporate a MODE command before both the DUMP? and the LOAD commands. If the DSA memory were to be restored with invalid data a total system corruption would occur. In this event it would be necessary to switch the DSA off and then on, and then to use "FUNCTION 78" to totally clear the memories (see Section R27.).

S1. DSA524 TECHNICAL SPECIFICATIONS

VERTICAL INPUT AMPLIFIERS

Number of channels	2.
Bandwidth	DC to 35MHz (10V/div to 20mV/div). DC to 20MHz (10mV/div). DC to 10MHz (5mV/div). DC to 5MHz (2mV/div).
Accuracy	± 3%.
Input Protection	400V DC or ACpk.

DIGITAL RECORDING SYSTEM

Vertical Resolution	8 bits (0.4%).
Recording Memory Size	4096 words per channel.
Max. Sampling Rate (single event signal)	20MS/s (single channel). 20MS/s (dual alternate). 5MS/s (dual chop).
Max. Storage Bandwidth (single event signal)	5MHz (4 samples/cycle) using sine inter-interpolation.
Max. Equiv. Sample Rate (repetitive signal)	2GS /s.
Max. Storage Bandwidth (repetitive signal)	35MHz.

TIMEBASE MODES

Normal	100ms/div to 5us/div.
Repeat (repetitive signal)	2us/div to 50ns/div.
Roll	200mins/div to 200msecs/div.

ACQUISITION MODES

Run	Acquisitions are repeated automatically.
Hold	Acquisition memory contents are frozen.
Single	Acquisition memories are updated once and then frozen.

TRIGGER MODES

Triggered	Acquisitions are only taken in synchronism with a trigger signal.
Auto	As triggered but acquisitions free run when there is no trigger signal.
Line	Acquisitions are taken in synchronism with AC line frequency.
Pre-trigger delay	The acquisition is stopped such that data prior to the trigger event is captured.
Post-trigger delay	The acquisition is stopped such that data after the trigger event is captured.

TRIGGER CONTROL SYSTEM

Source	CH1, CH2 or External.
Level	Variable ± 4.25 divisions or fixed (zero).
Sensitivity	Internal< 0.8 divisions, External < 300mV (DC to 5MHz). Internal < 3 divisions, External <1V (5MHz to 20MHz).
Slope	Selectable as positive or negative.
Coupling	Selectable as AC, DC or HF reject.
Time Delay	0 to 40 divs pre-trigger, 0 to 10,000 divs post-trigger (10 seconds max.).
Events Delay	Selectable 1 to 16 trigger events before acquisition.

OSCILLOSCOPE DISPLAY SYSTEM

Trace A	Displays 1024 words from either CH1 or any indexed waveform storage memory.
Trace B	Displays 1024 words from either CH2 or any indexed waveform storage memory.
Line Type	Selectable as individual levels (dots) or joined to form a smooth line.
Update Rate (Run Mode)	Selectable between 50 per second and one every 3 seconds (continuous in roll mode).

OSCILLOSCOPE DISPLAY VERTICAL CONTROL

Position	Continuously variable for each trace ± 4.25 divisions.
Gain Variable	Continuously variable for each trace between X1 and X0.2.
Invert	Displays trace B inverted.
Add	Adds trace B (normal or inverted) to trace A.
Multiply	Multiplies trace A by trace B.
Average	Displays the average of between 2 and 256 acquisitions.

OSCILLOSCOPE DISPLAY HORIZONTAL CONTROL

Compress	Compresses the whole 4096 words of the acquisition memory into the 1024 words of the trace memory.
Scan	Selects which block of 1024 words from 4096 is displayed.
Magnify (x10)	Expands any 102 word section of the memory ten times to fill the screen using digital liner interpolation.
Sine Interpolation	Re-constructs sinusoidal waveforms in magnify mode.

WAVEFORM STORAGE (NON-VOLATILE)

Digitising Memories	2 of 4096 words each.
Indexed Memories	16 of 1024 words each.
Storage Period	Potentially infinite, supported by trickle charged batteries, hold-up period 1month when un-powered.

PROGRAM STORAGE (NON-VOLATILE)

System	All controls are fully programmable and front-panel settings can be stored and re-called individually or in sequence. Maximum number of stored settings 50.

RS-423 INTERFACE (RS-232 COMPATIBLE)

Baud Rate	Selectable between 300 baud and 38,400 baud in 8 steps.
Write Functions	All front panel controls are fully programmable and can be set via the interface. The trace memories and indexed waveform memories can all have data written to them.
Read Functions	The front panel status can be read via the interface. Data can be read from the trace memories and the Indexed waveform memories.

HARDCOPY OUTPUT FACILITIES

Printer Interface	Links to dot-matrix printer (Epson quad density graphics compatible) via RS-423 interface. Prints stored waveforms plus annotation.
Digital Plotter Interface	Links to digital X-Y plotter (HP-GL compatible) via RS-423 interface. Plots stored waveforms plus annotation.
Analogue Plotter Interface	Provides simultaneous output of A and B traces for analogue chart recorder plus X output for X-Y plotter. Output 100mV/div. Speed 1,2,5 or 10 seconds per division. Pen lift/chart feed output 0 to 5V.
POWER REQUIREMENTS	110, 120, 220 or 240V ± 10% at 50/60Hz. 30VA max.

OPTIONS

GP-IB (IEEE-488) Interface	Provides all of the functions of the RS-423 interface via the General Purpose Interface Bus.
DS-PC Link	Software and firmware package which links the instrument to an IBM-PC compatible personal computer for waveform display and control.

S2. ELECTRICAL ISOLATION

The ground connections of the DSA are all connected to the ground conductor of the AC line supply. All exposed metal parts are also connected to this point. Consequently only equipment which is either floating or is already connected to AC line ground should be connected to the ground of the DSA.

S3. GENERAL SAFETY CONSIDERATIONS

This instrument has been designed to the highest safety standards, but safety depends on the user and the following basic precautions should be observed. The instrument is Class 1 by IEC classification.

i) Before connecting to an AC line supply, check that the unit is set to the correct voltage as indicated by the label at the rear.

ii) Ensure that an appropriate AC line plug is connected to the standard IEC cable supplied, and that a secure ground connection is made. Connections are brown = live, blue = neutral, green/yellow = ground.

iii) Remove power from the instrument before making any attempts to dismantle it.

S4. FUSE REPLACEMENT

The AC power fuse is mounted on the back panel within the AC line input socket housing. To replace the fuse pull the clip-in tray outwards. The active fuse is at the back of the tray, the front space is for a spare fuse.

The fuse must be replaced with a 500mA anti-surge 20mm cartridge fuse. A ceramic bodied HRC type should be used whenever possible.

S5. MAINTENANCE AND REPAIR

The manufacturers or their agents abroad will provide repair for any unit developing a fault. In the UK, defective instruments should be returned, carriage paid, to the manufacturer's service department. Careful and substantial packing is essential, no responsibility can be accepted for damage caused in transit to the manufacturer, if possible use the original packing material.

If the guarantee has expired or if the fault is the result of misuse, the repair will be carried out and charged unless other instructions are received.

Customers outside of the UK should contact the dealer or agent from whom the unit was purchased to ascertain service arrangements for that country.

S6. UPDATING THE FIRMWARE

From time to time small revisions may be made to the firmware of the DSA524 (the firmware is the ROM based program code for the unit). The firmware level is displayed briefly whenever the unit is first switched on (and when SET 'SCOPE is used) as DSA524 X.XX, where X.XX is the firmware level.

If the user should require an update to the latest firmware level at any time, new firmware can be obtained via the agent or distributor from whom the unit was purchased (or directly from Thurlby Electronics Ltd.) and can be fitted by the user. A small charge will be made for the new firmware.

S7. GUARANTEE

The instrument is guaranteed as free from defects in workmanship or materials. The terms of the guarantee will vary dependent upon the country in which it is sold. Information concerning the guarantee can be obtained from the dealer or agent from whom it was purchased. In the UK the guarantee period is 12 months.

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