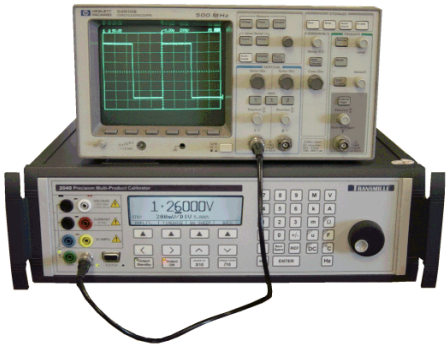
Oscilloscope Calibration Option

For the 2000 Series Calibrators

Cost Effective Oscilloscope Calibration Option SCP

- **Internal Retro-Fittable Option**
- **Economical scope calibration -** All the benefits at a fraction of the cost of a dedicated instrument
- **All outputs from one BNC**
- **Automate calibration using ProCal Calibration software**



Calibration module expands the capabilities of the 2000 Series calibrators to provide **Amplitude**, **Timebase** and **Bandwidth** calibration of oscilloscopes up to 600MHz. A fixed 50kHz reference is also incorporated. Output for all oscilloscope calibration module functions is through a single dedicated BNC connection with an associated 'active' indicator LED.

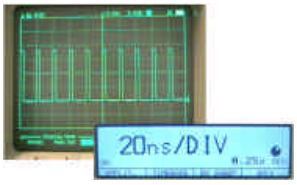
Amplitude

- **2mV/Div to 50V/Div**
- **1 - 2 - 5 Sequence**
- **10% Deviation**

Easily selected using the softkeys, the calibrator produces either a precision 1kHz square wave or a DC level covering the range from 2mV/Div to 50V/Div in a 1,2,5 sequence. Deviation up to 10% in 0.01% steps can be applied using the digital potentiometer. The calibrator's wide range output, giving up to 300V pk-pk, can be used to directly calibrate the ever increasing number of oscilloscopes with amplitude ranges up to 50V/Div placing it in a class leading position.

Timebase

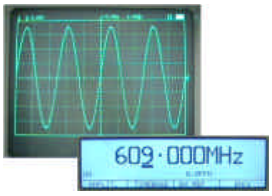
- **2ns/Div to 5s/Div**
- **1 - 2 - 5 Sequence**
- **10% Deviation**



The timebase function of the oscilloscope option provides outputs from 2ns/Div to 5s/Div in 1,2,5 Sequence. Deviation up to 10% in 0.01% steps can be applied using the digital potentiometer. To use, simply align the time marker with the graticule display and read the deviation from the % display on the calibrator. The comb waveform used below 100ns is ideal for triggering on both analogue and digital oscilloscopes alike. For faster timebase calibration, a sine wave is produced which makes viewing on bandwidth limited oscilloscopes easier. The timebase output can be used either directly or into a 50 Ohm input.

Levelled Sweep

- **5MHz to 620MHz**
- **50kHz Reference**
- **600mV pk-pk**



The levelled sweep output of the oscilloscope option provides a continuously variable sine wave from 5MHz to 620MHz. A 50kHz reference level waveform is also available to allow the oscilloscope controls to be set to give a 6 graticule height display.

Automated calibration Using ProCal

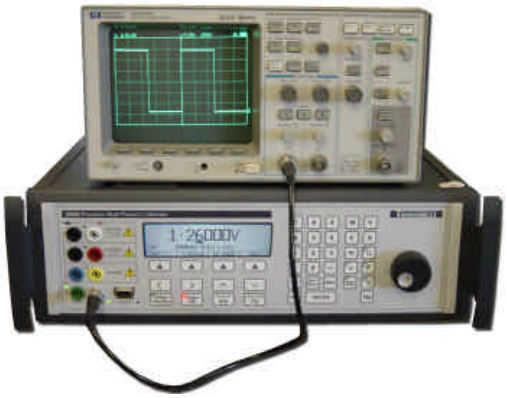
When used with ProCal, a calibration procedure automatically sets calibrator and guides the operator, recording the results and producing a printed certificate if required saving time and reducing skill levels while improving quality and efficiency.

Specifications

Amplitude : 2mV/Div to 50V/Div • 1-2-5 Sequence • 10% Dev.
Timebase : 2ns/Div to 5s/Div • 1-2-5 Sequence • 10% Dev.
Bandwidth : 5MHz to 620MHz • 50kHz Ref. •600mV pk-pk

See extended specifications for full details

Calibrating Oscilloscopes - Applications



Introduction

Oscilloscopes have always been an important measurement tool for the engineer. The design of oscilloscopes has evolved slowly from early instruments which were used to simply view a waveform, to oscilloscopes with calibrated ranges and graticules (grid) on the display to enable measurements to be made, up to the modern digital storage oscilloscope (DSO) which have many advanced measurement functions built in as standard.

The latest designs now use digital LCD displays instead of the tradition CRT (cathode ray tube) and are putting even more measurement power in the hands of the engineer in ever more portable instruments. The oscilloscope is still evolving, the latest step is the scope meter which combines the functions of an oscilloscope with those of the DMM in one instrument. Each evolutionary step has added to the measurement capability of the oscilloscope, making the calibration of these instruments even more important.

The large number of ranges, channels and functions of oscilloscopes can make the calibration process time consuming and hence expensive which has lead to, in some cases, the oscilloscope being marked 'DISPLAY USE ONLY' calibration not required - this limits the usage of an otherwise very power measurement tool. The solution is more efficient calibration which is provided by the 2000 series calibration option and ProCal software.

Oscilloscope Types

There are three basic types of oscilloscope in common usage which the calibration laboratory may need to calibrate.

1) *Simple oscilloscopes* - usually dual channel with direct display on CRT.

2) *Digital storage scope* (DSO) with readout

3) *Hand held* Scope meters

All types are available with different bandwidths, but the bulk of oscilloscopes have bandwidths less than 200MHz with very few having bandwidth above 600MHz.

The bandwidth rating is a measure of the oscilloscopes ability to display high frequency, and as a guide the higher the bandwidth the more features a scope will have.

All types of oscilloscopes require calibration of three main functions.

Vertical Deflection / Amplitude

- Typical ranges from 2mV/Div to 50V/Div

Ranges are normally in a 1,2,5 sequence, calibration is carried out using a 1kHz square wave positive going from ground, 6 graticules high. As it is impossible to read the error accurately from the scope display the calibrators output is slewed (Increased or Decreased) to align the trace with the graticules. On some scopes, especially if fitted with readout a DC voltage is needed for calibration which can also be provided by the 2000 series calibrator.

Notes

1) Parallax errors

It is important to view the display straight on to avoid any parallax errors. This only applies to the older scopes, many modern digital scopes also display the graticules digitally on the screen.

2) Calibrate Each range
Even the high ranges as any range could have been damaged by the user applying excessive voltage to the input.

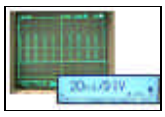
3) Shock Risk
The 2000 Series option produces voltages up to 300Volts needed for the calibration of the high ranges (50V/Div x 6 = 300Volts) found on some scopes.

4) Noise On Low Ranges
This can be reduced by using the scopes bandwidth limit function if fitted.

5) Ground Loops
An oscilloscope's input is almost always at power line earth - if the 2000 series also has the output grounded then noise / offsets could be caused by ground loop currents flowing between the power ground of the scope and that of the calibrator.

To calibrate amplitude with the 2000 series select 'Scope' from the soft menu keys, then amplitude. Use the range keys, stepping up or down through the ranges to match that of the scopes. Slew the calibrator using the digital pot to align waveform.

The Horizontal Deflection / Time Base Calibration.



- Typical ranges from 5s to 2ns

Calibration is performed using a comb type wave form which can easily be aligned to the graticule scale. This works well up to 100ns where bandwidth limits the use of very short pulses, so a sine wave is used instead. Like amplitude, the calibrators output is slewed to accurately align the first and ninth pulse up on the graticule scale. The error can then be read from the deviation applied by the calibrator. The linearity of the horizontal sweep can also be checked by looking at the alignment of every pulse.

Notes

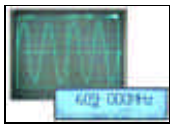
1) To help get the scope set to the correct settings for amplitude/trigger etc. use a midrange marker first, 1ms for example, auto-scale on DSO's will, in particular, find this waveform easily and set trigger and amplitude range for you.

2) Set the coupling to DC and the trigger mode to 'NORM' to capture slow time markers. Auto trigger may start the sweep before the first pulse.

3) Using a 50 Ohms input will improve the shape of the waveform but makes no difference to the accuracy of calibration.

To calibrate timebase with the 2000 series select 'Scope' from the soft menu keys, then Time. Use the range keys, stepping up or down through the ranges to match that of the scopes, slew the calibrator using the digital pot to align waveform.

Bandwidth / Leveled Sweep
From 5MHz upwards



Calibration of bandwidth requires a constant amplitude sine wave of variable frequency up to and above that of the oscilloscopes specification. Many calibration procedures also call for a 50kHz reference level to set the start amplitude.

Calibration involves setting the scope to display the 50kHz ref level at 6 graticules high then increasing the frequency until the waveform is only 5.4 graticules high (the 3db point). The frequency at this point is the bandwidth. On increasing the frequency the display should also be checked for any 'highs' or flat spots to ensure a level response. Bandwidth can also be obtained by using a fast rising edge (formula Bandwidth MHz =)

Notes

Bandwidth must be measured with either the oscilloscope's 50 Ohm input selected or an external feed through line terminator fitted to the oscilloscope's input.

To calibrate bandwidth with the 2000 series select 'Scope' from the soft menu keys, then bandwidth. Ensure the oscilloscope input is 50 ohms. Set the oscilloscope amplitude to show the waveform at 6 divisions high using the 50 kHz ref level selected from the soft keys, then return to the leveled sweep output increase the frequency until the 3db point (5.4 div high) is reached.

Trigger Level & Sensitivity

Trigger level can be tested by using a sinusoidal signal at 6 divisions high and adjusting the trigger level control to produce a stable trace starting at any point on either the positive or negative slope depending on scope selection. Sensitivity is tested by applying a much smaller signal (typically 10% of FS) and checking a stable trace can be obtained even when the position controls are used to move the trace to the top or bottom of the display. Bandwidth of the triggering and operation of the HF noise filters on some scopes can be tested by using the leveled sweep output and increasing the frequency or until stable triggering is lost. See oscilloscope manual for method and levels.

Other Parameters

There are many other functions on oscilloscope's which may require testing are listed below, The scopes manual will give the manufacturers recommend methods for testing other features which can be tested as required.

Display Geometry
Mainly for older scopes with separate graticules screens which require mechanical alignment with the CRT which may also need trace rotation to be adjusted.

Display & Controls
Operation of brightness, focus, astigmatism and position controls.

Selection of vertical channel operation
Chopped/Alternate/channel 1,2 etc.

DC balance
The change in DC level between ranges.

Input Coupling Selection
AC/DC/50 ohm/Gnd

Pulse Response
Leading edge Aberration.

X Input operation and bandwidth
For scopes with 'X' inputs

Vertical & Horizontal X10 function:

Trigger mode selection
Ch1, Ch2, Int, Ext, DC couple, noise reject, +/-ve edge etc

Time base mode selection
Auto, norm, hold off etc

Delay Time base operation and accuracy.

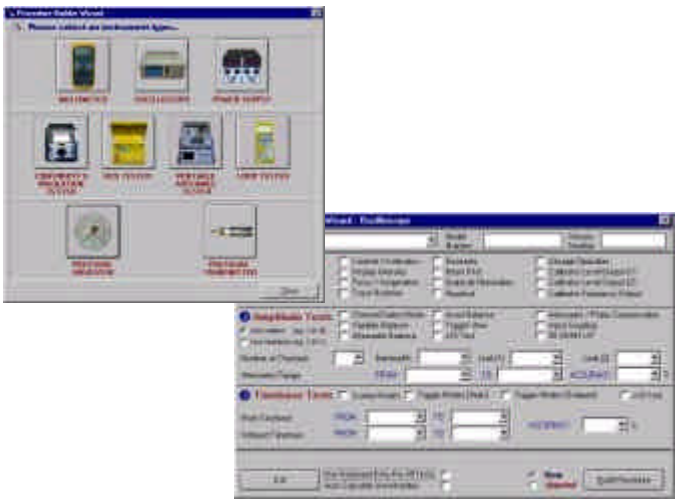
Cursor Readouts
Frequency, period, pk-pk amp, etc.

Automating Oscilloscope Calibration Using ProCal Software

Oscilloscope calibration can be fully automated by using ProCal to control the 2000 Series calibrator and even the oscilloscope under test using a PC. The 2000 Series calibrator is controlled via the RS232, removing the need for expensive interface cards. Alternatively, control can also be achieved via the GPIB interface option if required.

ProCal can also utilise its ability to control instrumentation via the RS232 or GPIB interfaces to automatically set the oscilloscope under test as well as the 2000 Series oscilloscope option, providing complete automation. This technique of controlling the 2000 Series calibrator and the UUT in this manner can be employed in many types of calibration, making ProCal a true multi-discipline software solution.

The ProCal oscilloscope calibration *procedure wizard* is one of a set of wizards which can assist in automatically creating procedures based on simple high level information such as ranges, number of channels, accuracy etc. Using these procedure wizards a procedure can be created in a matter of minutes.

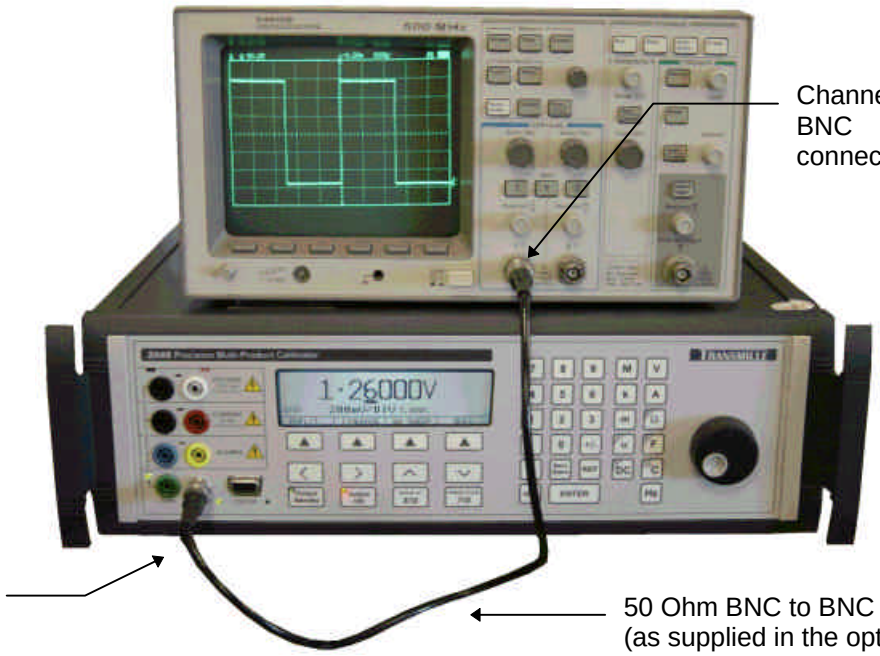


Oscilloscope Calibration Option - Operation

The oscilloscope calibration option can provide Amplitude, Time base and Bandwidth signals for calibration of oscilloscopes.

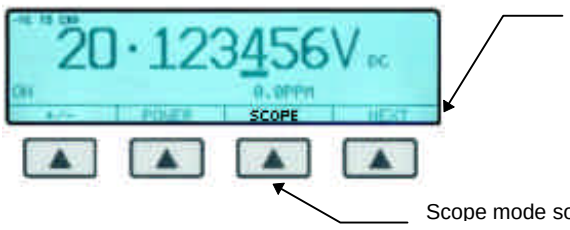
Oscilloscope Connection

Using a BNC to BNC 50 Ohm coax cable, connect the 2000 Series calibrator SCOPE BNC output connector to the oscilloscope connector (to begin with connect to channel 1, the progressively test each channel by connecting to any other additional channel input connectors as necessary).



Starting the Oscilloscope Calibration Option

To start the oscilloscope calibration option, press the softkey below the SCOPE menu item

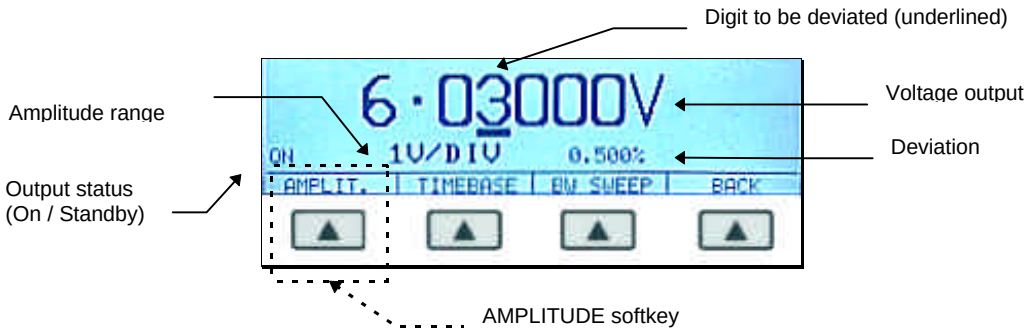


Oscilloscope Calibration : Amplitude

The oscilloscope amplitude is calibrated by applying a low frequency square wave and adjusting its gain to meet the height specified for different voltage levels (shown by the graticule line divisions on the oscilloscope).

The voltages that are used for calibration are selected using the corresponding setting as per the amplitude ranges on the oscilloscope. Using this output the waveforms should be aligned with the graticule markings on the oscilloscope display.

On entering oscilloscope mode, AMPLITUDE will be the default function. The display below will be shown indicating the currently selected range and output status :



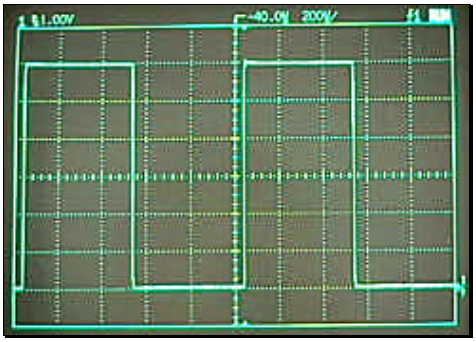
When calibrating the oscilloscope's amplitude gain, you will need to set different voltages and check that the gain matches the graticule height lines on the display of the oscilloscope within the specifications as supplied by the oscilloscope's manufacturer.

1. Using a BNC to BNC type lead (such as the lead supplied with the optional precision lead set available from Transmille) connect the 2000 series BNC connector to the oscilloscope Channel 1 BNC connector. Set the oscilloscope to the required range.

2. Using the RANGE UP **X10** RANGE DOWN **/10** buttons, select the range required, e.g. 200mV/Div and ensure the calibrator output is turned ON by pressing the Output ON key.

Note : The LED in the top left hand corner of the Output ON key will illuminate and the display will indicate **ON** in the left hand corner.

3. Adjust the oscilloscope to display the waveform as shown below :



Graticule height = 6

4. To determine the deviation from nominal of the oscilloscope, use the deviation function to alter the output. This is controlled by using the keys to select the required digit on the voltage display (indicated by the underlined digit) then using either the keys or the digital potentiometer to increment or decrement the digit value

Increment Decrement

ⓘ Note : The % of deviation is shown in the bottom right hand side of the calibrator's display

For example if the displayed amplitude waveform was HIGH on the oscilloscope display, the value would be deviated down to the value at which the amplitude was within six graticules on the oscilloscope display for the waveform displayed above.

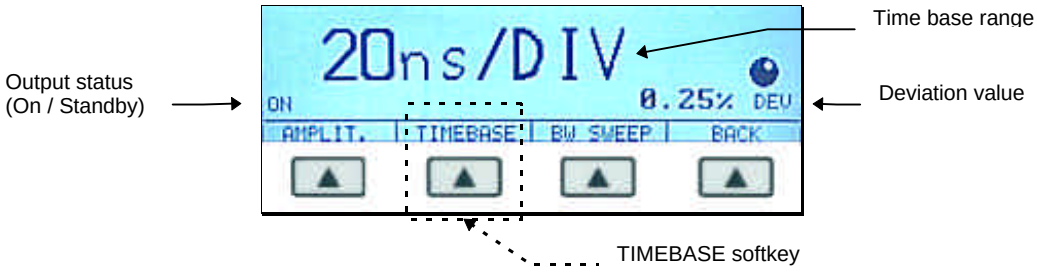
Note : The graticule height is set to 6 as default

5. The above operation should be performed for all of the ranges and on each of the channels on the oscilloscope. This normally lengthy process can be significantly reduced by using the ProCal calibration software available from Transmille which allows a pre-defined sequence of tests (known as a procedure) to be set up. This allows the computer to automatically step through these tests, control the calibrator, set the correct outputs and record the amount of deviation in relation to the oscilloscope's specifications.

Oscilloscope Calibration : Time base

The time base of an oscilloscope is calibrated to ensure the horizontal deflection meets the manufacturers specifications. A time marker signal is generated from the calibrator of which the peaks are aligned with the graticule scale on the oscilloscope display.

Select the TIMEBASE function using the softkey located beneath the TIMEBASE menu item.
The display below will be shown indicating the currently selected range and output status :

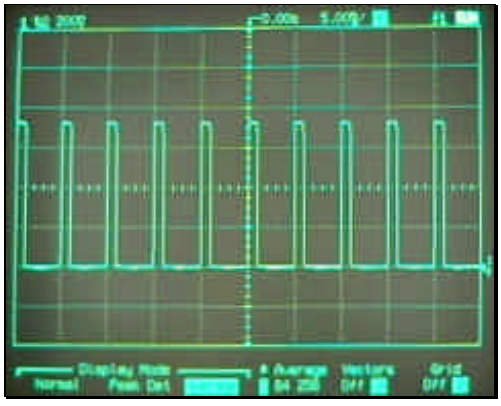


1. Using a BNC to BNC type lead (such as the lead supplied with the optional precision lead set available from Transmille) connect the 2000 series BNC connector to the oscilloscope Channel 1 BNC connector. Set the oscilloscope to the required range.

2. Using the RANGE UP **X10** RANGE DOWN **/10** buttons, select the range required, e.g. 20ms/Div and ensure the calibrator output is turned ON by pressing the Output ON key.

Note : The LED in the top left hand corner of the Output ON key will illuminate and the display will indicate **ON** in the left hand corner.

3. Adjust the oscilloscope to display the waveform as shown below - the time marker signal peaks should be aligned with the divisions marked on the oscilloscope display :



4. To determine the deviation from nominal of the oscilloscope, use the deviation function to alter the output. This is controlled by using the digital potentiometer to increment / decrement the time marker signal.


Increment


Decrement

ⓘ Note : The % of deviation is shown in the bottom right hand side of the calibrator's display

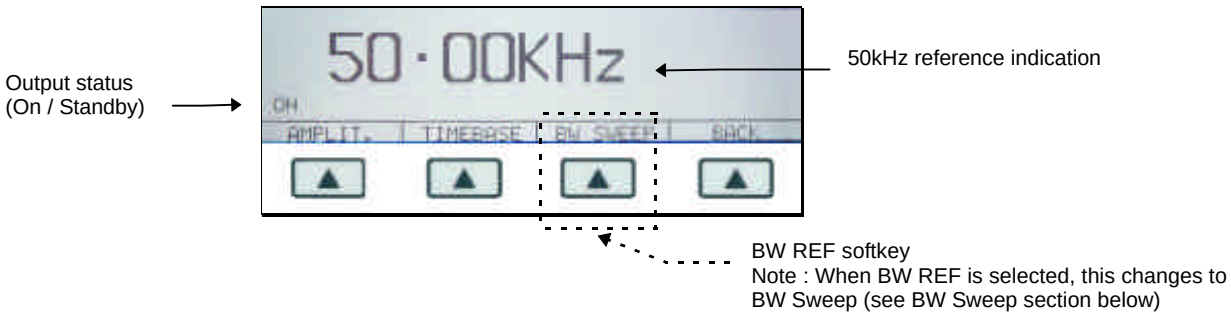
5. The above operation should be performed for all of the time base ranges on the oscilloscope.
This normally lengthy process can be significantly reduced by using the ProCal calibration software available from Transmille which allows a pre-defined sequence of tests (known as a procedure) to be set up. This allows the computer to automatically step through these tests, control the calibrator, set the correct outputs and record the amount of deviation in relation to the oscilloscopes specifications.

Oscilloscope Calibration : 50kHz Reference

The 50kHz bandwidth reference output of the 2000 series calibrator should be used to set an oscilloscope to display a waveform which is 6 graticules high by adjusting the amplitude gain (Volts / Div setting). This allows the oscilloscope to be correctly configured prior to performing bandwidth verification (detailed below), ensuring that when bandwidth sweep is selected the user can simply increase the frequency and determine the -3dB point (4.2 graticules) accurately.

In order to select the bandwidth reference (50kHz), it is necessary to select the BW SWEEP (Bandwidth Sweep) function first using the softkey. Once BW Sweep is selected, the menu item will change to indicate BW REF - simply press the softkey under this menu item to set the BW REF mode.

The display below will be shown indicating the current frequency and output status :



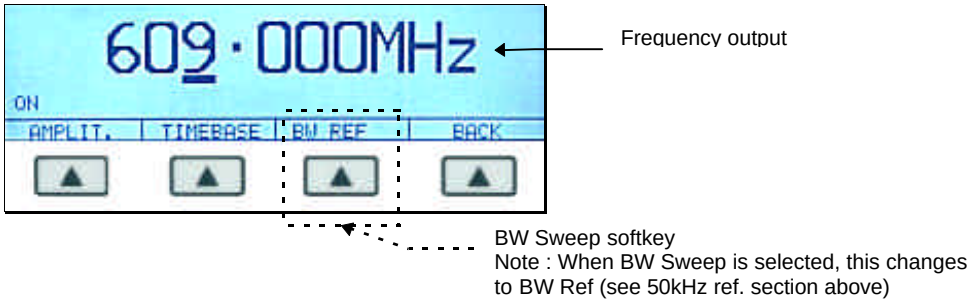
Ensure the calibrator output is turned ON by pressing the Output ON key.

Note : The LED in the top left hand corner of the Output ON key will illuminate and the display will indicate **ON** in the left hand corner.

Oscilloscope Calibration : Bandwidth Sweep

The bandwidth calibration output of the 2000 series calibrator produces a levelled sine wave with a constant amplitude over its frequency span. To check the bandwidth of an oscilloscope this levelled sine wave is applied and the frequency gradually increased until the amplitude displayed on the oscilloscope display drops by 30% (this is the amplitude corresponding to the -3dB point)

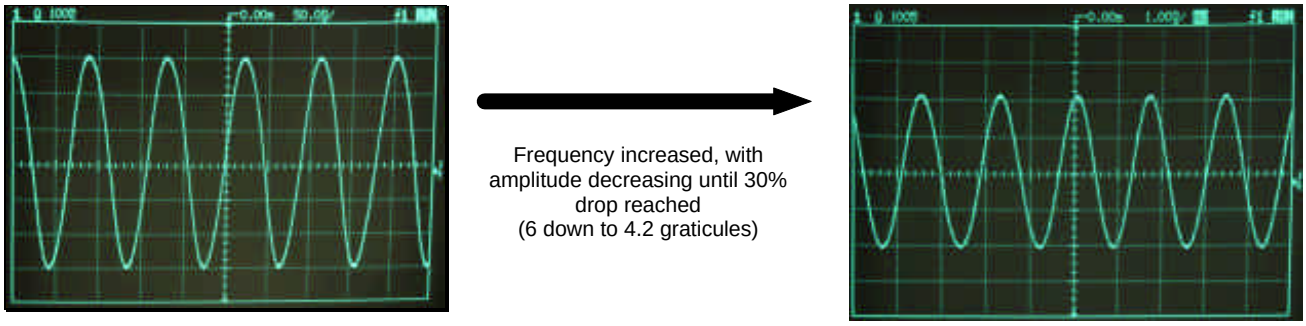
Select the BW SWEEP (Bandwidth Sweep) function using the softkey.
The display below will be shown indicating the current frequency and output status :



1. Using a BNC to BNC type lead (such as the lead supplied with the optional precision lead set available from Transmille) connect the 2000 series BNC connector to the oscilloscope Channel 1 BNC connector. Ensure the correct termination is used when connecting to the oscilloscope (for example 50 Ohms). Set the oscilloscope to the required range.

2. Using the digital potentiometer, select the required start frequency, e.g. 3MHz

3. The oscilloscope should display the waveform as shown below :



4. Gradually increase the frequency output from the calibrator by using the digital potentiometer until the waveform drops by 30% (this can be seen when the waveform drops from 6 graticules to 4.2 graticules high)

Increment

Decrement

5. The above operation should be performed for all of the time base ranges on the oscilloscope.
This normally lengthy process can be significantly reduced by using the ProCal calibration software available from Transmille which allows a pre-defined sequence of tests (known as a procedure) to be set up. This allows the computer to automatically step through these tests, control the calibrator, set the correct outputs and record the amount of deviation in relation to the oscilloscope's specifications.

2000 Series Oscilloscope Calibration Option Specifications

Amplitude	
Ranges	2mV/Div : 5mV/Div : 10mV/Div : 20mV/Div : 50mV/Div : 100mV/Div 200mV/Div : 500mV/Div : 1V/Div : 2V/Div : 5V/Div : 10V/Div : 20V/Div : 50V/Div
Sequence	1, 2, 5
Waveshapes	Square Wave (positive going from ground) : DC
Frequency	1kHz
Frequency Accuracy	30ppm
Graticule Height	6 Graticules
Rise Time	2us
Fall Time	2us
Output Terminal	Front BNC (Green LED indicates terminal active)

Range	90 Day Rel.			180 Day Rel.			1 Year Rel.			2 Year Rel.		
@ 1Mega Ohm loading	%	±	uV	%	±	uV	%	±	uV	%	±	uV
2mV to 50V/Div	0.009	±	5	0.01	±	5	0.01	±	5	0.014	±	5

High Voltage Safety

High voltage output is ramped to allow instruments to auto range
Auto standby is activated when passing through 20V or 200V output values
High voltage (> 20V) output is indicated to user through an audible warning beep
An external high voltage output/standby control switch is available as an option

Amplitude Deviation	
Deviation Range	±10%
Deviation Resolution	2006A : Better than 1ppm • 2041A : Better than 10ppm

Range	90 Day Rel.			180 Day Rel.			1 Year Rel.			2 Year Rel.		
	%	±	uV	%	±	uV	%	±	uV	%	±	uV
-10% to +10%	0.008		5	0.01	±	5	0.01	±	5	0.014	±	5

Timebase	
Ranges	2ns/Div : 5ns/Div : 10ns/Div : 20ns/Div : 50ns/Div : 100ns/Div : 200ns/Div 500ns/Div : 1ms/Div : 2ms/Div : 5ms/Div : 10ms/Div : 20ms/Div : 50ms/Div 100ms/Div : 200ms/Div : 500ms/Div : 1s/Div : 2s/Div : 5s/Div
Sequence	1, 2, 5
Waveshape	Comb below 100ns Sine Wave above 100ns
Oscillator	Internal Crystal TCXO
Output Terminal	Front BNC (Green LED indicates terminal active)

Range	90 Day Rel. ppm	180 Day Rel. ppm	1 Year Rel. ppm	2 Year Rel. ppm
2ns/Div to 5s/Div	4.5	4.75	5	6

Timebase Deviation	
Deviation Range	±10% in 0.05% Steps
Deviation Resolution	Better than 0.05%

Range	90 Day Rel. %	180 Day Rel. %	1 Year Rel. %	2 Year Rel. %
-9.5% to +9.5%	0.01	0.01	0.01	0.01

Levelled Sweep				
Sweep Range	5MHz to 600MHz[1]			
Waveform	Sine Wave			
Levelled Sweep	600mV pk-pk into 50 Ohms			
Reference Level	50kHz			
Output Terminal	Front BNC (Green LED indicates terminal active)			
Range	**90 Day Rel. db**	**180 Day Rel. db**	**1 Year Rel. db**	**2 Year Rel. db**
5MHz to 600MHz[1]	0.8	0.90	1	1.4

Note 1 : 2050 Bandwidth range is 5MHz to 250MHz

Levelled Sweep	
Frequency Accuracy	See Timebase

50kHz Reference				
Accuracy	**90 Day Rel.**	**180 Day Rel.**	**1 Year Rel.**	**2 Year Rel.**
Frequency Accuracy	27 ppm	29 ppm	30 ppm	36 ppm
Level Accuracy	0.4 %	0.45 %	0.5 %	0.7 %

Specifications apply between 17°C and 27°C.

Outside this range an allowance of 0.18 x 1 Year Spec. per °C should be added.

Due to continuous development specifications may be subject to change.