Scope & DMM Calibrator

By G8MNY (Updated Sep 13)
(8 Bit ASCII graphics use code page 437 or 850, Terminal Font)

This device lets you test the basic accuracy & frequency response of a scope's input attenuator & allow accurate adjustment of the compensation trimmers, & also test Meter calibration.

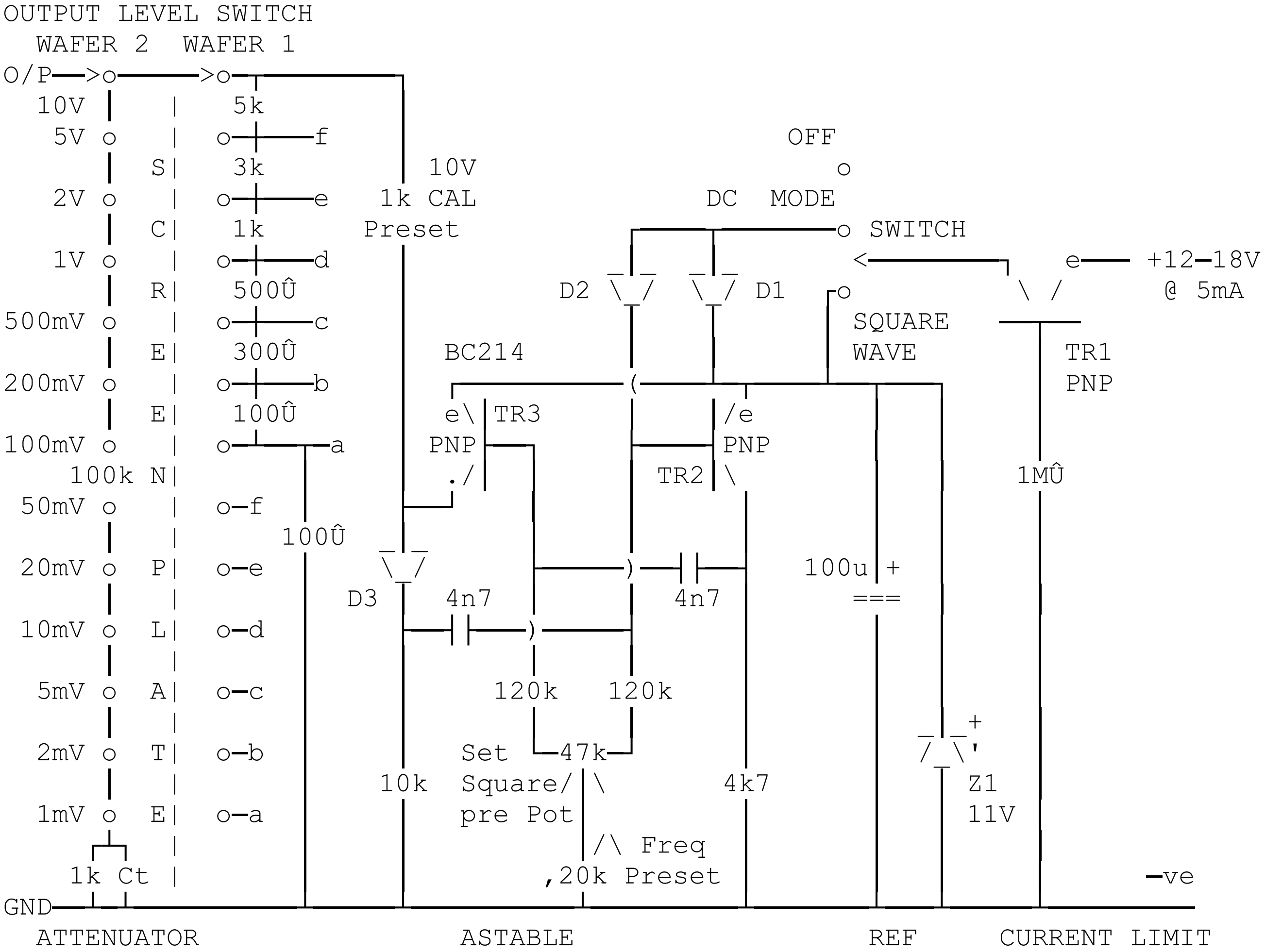
The design gives accurate DC or 1kHz square wave voltages from 10V p-p down to 1mV p-p in 10, 5, 2, 1 steps.

The rise time (not fall time!) is better than 100nS @ 10V, but the attenuator Rs & stray capacitance can double this on the 5 & 2V ranges.

It can also be used for checking other DVMs or other high input Z meters.

CIRCUIT

Based on a simple PNP astable, reference voltage source, & output attenuator..



POWER

TR1 (BC214) provides a limited current source (Approx 5mA) controlled by the 1MÛ base resistor, to put current into an 11V Zener Z1 & the rest of the circuit. Although this current source varies a little with the supply & temperature it is much better than just a resistor, & hence the zener reference voltage (5+6V zener) gives say 10.8V ±10mV, is kept fairly accurate!

If the +10V range is not wanted the circuit can be worked with a 5.6V zener, a PP3 battery & suitable attenuator changes! For higher voltages different circuits are needed with diodes to protect the bases from overvoltage.

DC MODE
When the DC mode is selected D1 (1N4148) powers the circuit, while D2 inhibits TR2 from conducting & hence T3 must conduct in the normal way providing an identical +ve output voltage to that when the circuit oscillates. D1 voltage drop should be of no consequence due to the constant current from TR1.

ASTABLE MODE
The TR2 & TR3 (BC214) make up the normal if up side down astable circuit. Diode D3 isolates the charging up of T2 base capacitor from the T3 output, so keeping the edge turn on very fast.

The frequency is determined by both sets of C & R (4n7 & 120k) time constants so the Cs should be polyester type for best thermal stability. Any in-balance of the square wave (not 1:1 ratio on a scope) can be adjusted by trimming the set square pot. Using a common 20kÛ preset to trim the joint bias will allow the frequency to be trimmed to exactly 1kHz with a frequency counter.

10V CALIBRATION
This is done using a accurate DVM (>1M Input Z). Set the mode switch to DC & set the output to switch to 10V, adjust the 1k Cal pot for 10.000V. Check that this DC is the same value as the 1kHz square wave rises to, on an oscilloscope.

ATTENUATOR
The attenuator resistance values are made up so that 10mV/1k ohm gives easy numbers to work with. But the 5k=10k//10k, 3k=3.3k//33k or 2x 1.5k etc. need 2 Rs to make the exact value from the E12 resistor series. All the Rs are soldered around the switch. I used a screened 2 bank 13 step switch, other switches will do with the Rs made up the values to suit.

The 6 positions out of the 1st 7 positions on the 1st wafer bank are paralleled up to the last 6 positions, which sees the 2nd wafer bank switch in a 100:1 attenuator, which uses high enough values not to significantly load the 1st attenuator values. Open wire low capacity wiring is needed for all the wiring in this area, e.g. NO "neatly tied up wiring forms", just short looped wires!

For accurate work (1% or better) the R values can be trimmed with much higher value Rs to ground or 10V using an accurate DVM as for the initial 10V calibration.

If the 5V output impedance is too high (2.5k=5k/5k) for some loads, put a 5k6 from the 5V point to ground & change the 10k//10k for 2k7//68k, the 68k value needs to be selected on test to give 5V once the 10V CAL is setup again.

For a good square wave on the low signals end of the attenuator, a screening plate is required between the dual bank switch, & possibly a trimming "Ct" to ground (1-20pF) across the 1k to over come crosstalk from the 10V to 1mV circuits.

CALIBRATING A SCOPE INPUT ATTENUATOR.
This assumes you are OK with working inside live scopes with HIGH VOLTAGES!

Connect the calibrator with a very short coax cable. With the scope at maximum Y1 gain setting, but without any added gain multiplier (as these reduce the bandwidth), select a suitable calibrator square wave signal level to give a 2—5cm display, using timebase controls to show 0.2cm/mS to give a large steady trace.

STEP 1. Check front panel Y1 Gain is set to "Cal" position. Adjust internal Y1 preset gain (not high gain X10) for correctly calibration height avoid display parallax error. Adjust preamp C/Rs tweaks for best (ideal) square rising edge response. Check the X10 (or whatever) gain option is also accurate adjust that high gain preset, if there are separate C/Rs for X10 also adjust.

N.B. some scopes have HF C/Rs that will not be adjustable with a 1kHz square wave but need faster 1MHz or RF frequency sweeps to set up.

```
     TO LITTLE HF            CORRECT              TO MUCH HF
     ____        _        ______        __       |`\.___
  ,/'    |     ,/'       |      |         |       |      |    | = faint
  |      |     |         |      |      |       |      |      |    | Verticals
  |      |     |         |      |      |       |      |      |
  |      `\.___|         |      |______|       |      |  ___|
                                                      |./'
```

STEP 2. Switch Y input attenuator to next position & up the calibrator level to suit, check defection calibration (do not adjust scope calibration unless you have suitable replacement scope attenuator Rs!), adjust the correct Y attenuator's series C (Ctrim) for best (ideal) square rising edge response. There may be two Cs, a series one (Ctrim) & a parallel one (Cstray), this one seems to do nothing at this stage!

Repeat this for the first set (order) of input attenuators.

```
                   Typical x10 x100 x1000    Typical x2 x3 or x5
SCOPE                    Attenuator                Attenuator
INPUT  o)──┤├─────>o─┬───┤├──────┬─o<───>o─┬───┤├──────┬─o<─── AMP INPUT
 BNC     │ AC │  SW  │   Ctrim   │   SW  SW │   Ctrim   │  SW    Input Z
Input Z  └─o \┘      ├─Rseries───┤          └─Rseries───┤        1MÛ //
1MÛ //     DC        │           │                      │         30pF
 30pF               ===Cstray  Rshunt                Rshunt
                     │           │                      │
       ──────────────┴───────────┴──────────────────────┴──────
       Both Attenuators banks are straight through wires for x1.
```

STEP3. Higher order attenuators (x10, x100, x1000) must "see the same load capacitance" of the first order attenuators so they can only be adjusted once the sensitive ranges have been done.

STEP4. Equalising the scope input capacitance (Cstray) across these ranges is best done with a x10 scope probe. Set the Y attenuator gain attenuator to its max sensitivity, with the X10 scope probe, view a suitable sized square wave. Adjust the probe's own trimmer for the best waveform. Now step up the scope Y attenuator over the ranges with suitable input levels, if the square wave shape changes, adjust the unused (did nothing before) parallel Y caps (Cstray) for the same shape. Remove the scope probe.

Now repeat step 3 & 4 until there is no tweaking needed. Go & adjust Y2!

STEP 5 TIMEBASE CALIBRATION
Make sure the Timebase velocity control is in its "Cal" position. Find the LF timing preset & adjust (sometimes it is the X gain) so that the 1kHz waveform fits a 1mS/Division range (|~|_| cycle in each square). Check on some of the other ranges for a mean calibration. For HF timebase calibration you will need an RF signal generator.

STEP 6 XY MODE/X IN
If it has these modes, then they can be calibrated for the correct gain to, in the same way as STEP 1, but U just see 2 dots unless U can put a locked timebase into Y.

AC RMS SCALED & TRUE RMS METERS

Using a square wave to calibrate RMS meters is not as complex as it may seem. On AC, most meters are MEAN reading, but calibrated in RMS for sine wave use. The sine wave mean is 0.636 of the peak, compared to the RMS value of 0.707 of the peak, so the readings are scaled higher. The error is exactly 1.11 which is called the "form factor".

```
  100%_|     _      __PEAK       100%_||__________  __RMS = 5V
 70.7%_|   /' `\     __RMS        +5V  ||          |
 63.6%-|  |     |    --MEAN            ||          |  1:1
       | |       |                     ||          | SQUARE
       ||         |                    ||          |
   0% -||- - - - -|- - - - -|     0% - || - - - - -| - - - - -|
       |          |         |          |           |          |
       |           |       |           |           |          |
       |            |     |            |   AC      |          |
       |             \._./         -5V_| COUPLED   |__________|
```

So back to the square wave of 10V p-p (DC component removed with a series cap if needed) this is a 5V peak square wave, which actually has the same RMS value as 5V DC, & will read 5V on a true RMS meter. But a MEAN reading meter which is scaled x1.11 higher & will read 5.55V AC.

DC MEAN METERS

The same goes for a square wave, 10V peak 50% of the time (what the square wave should be!) should read 5V, but 7V RMS. So you can determine if a meter is MEAN reading DC or not.

```
 100%_||__________           __PEAK = 10V
      ||          |
      ||          |  1:1     --RMS = 7.07V
      ||          | SQUARE
      ||          |
 50% -|| - - - - -| - - - - -| --MEAN 5V
      |   50% ON  | 50% OFF  |
      |           |          |
      |   DC      |          |
  0% _| COUPLED   |__________|  __0V
```

DC METER CHECKS

With the Calibrator on DC mode, any reasonably high impedance meter can be tested for basic accuracy & damaged or burnt out meter calibration Rs detected.

Also see my Tech buls on "Oscilloscopes", "Scope Probes" & "Kelvin Varley Voltage Divider".

Why Don't U send an interesting Bul?

73 De G8MNY @ GB7CIP