

An Operator Reaction Time-Free Stopwatch Calibrator

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Rationale

-  Manual hand synchronization method of calibrating stopwatches is fraught with start / stop operator reaction time
-  Start / Stop operator reaction time contributes a significant part of overall calibration uncertainty
-  This electro-mechanically operated Stopwatch Calibrator was developed to eliminate operator reaction time and ensure synchronized start / stop operation of stopwatch and time standard



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Description of Stopwatch Calibrator

 Consists of a magnetic contactor with plunger coupled to its armature that pushes the start / stop buttons of the Stopwatch

 Magnetic contactor switch contact opens and closes a 'gate' to allow a train of pulses of known duration (from traceable Frequency Standard) to be accumulated by a Frequency Counter in Totalize mode

 Difference between the observed Stopwatch indication and the accumulated number of timing pulses is the bias of the Stopwatch under calibration for the timing period tested

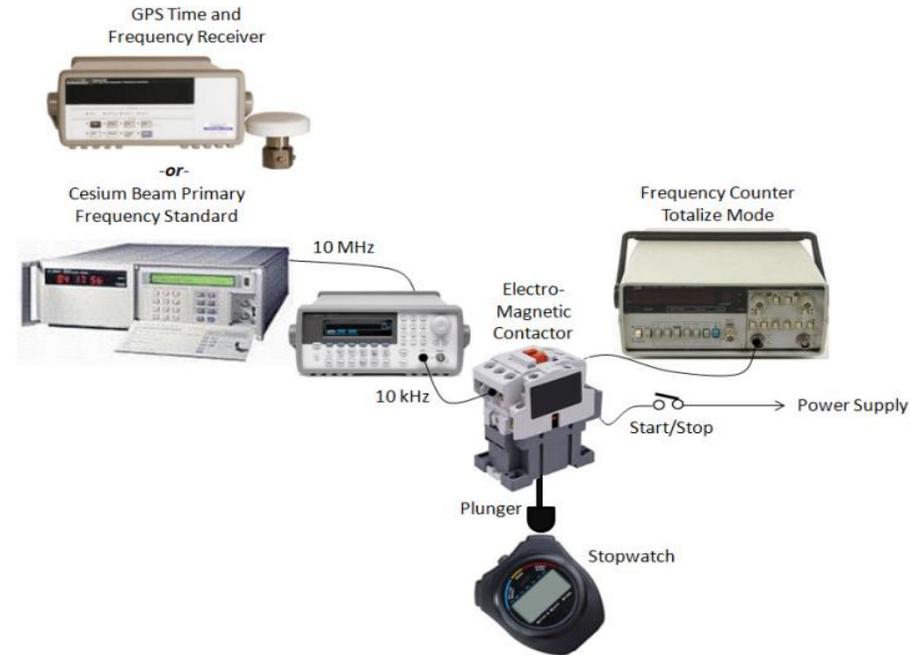


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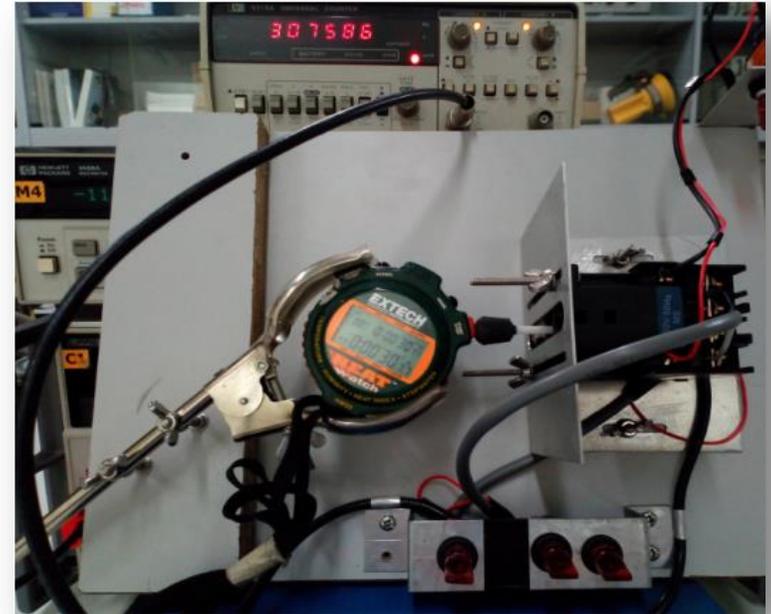
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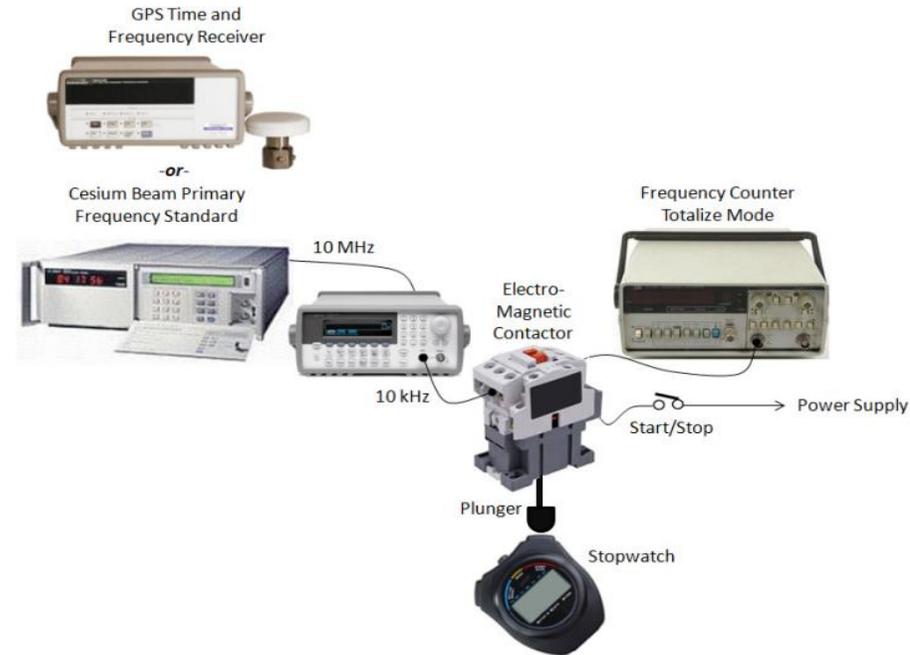
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Description of Stopwatch Calibrator

Because the Stopwatch Calibrator's switching mechanism is electro-mechanically operated

- any start /stop time delays between the Stopwatch and the Reference Timer is consistent,
- any time delay that appears at the start also appears at the end of the timing period that effectively cancels out when differenced



Sample Calibration Results

A. Stopwatch with 'soft-operating' start/stop push button switch

Start / Stop Time Delay, Ave	0.007 s
Std Dev of the mean	0.004 s
Observation Time	10 s

B. Stopwatch with start/stop push button switch requiring firm force and 'click' to actuate

Start / Stop Time Delay, Ave	0.059 s
Std Dev of the mean	0.008 s
Observation Time	10 s

Stopwatch Pushbutton Characteristics

Soft-operating	Hard-operating
produces negligible start / stop delays	produces appreciable start / stop delays
produces consistent timing operation	produces inconsistent timing operation

Sample Calibration Results

A. Stopwatch with 'soft-operating' start/stop push button switch

Start / Stop Time Delay, Ave	0.007 s	Timing Difference, Ave	-0.006 s
Std Dev of the mean	0.004 s	Std Dev of the mean	0.006 s
Observation Time	10 s	Observation Time	900 s

Timing Bias (corrected for Start / Stop Time Delay)	0.001 s
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B. Stopwatch with start/stop push button switch requiring firm force and 'click' to actuate

Start / Stop Time Delay, Ave	0.059 s	Timing Difference, Ave	-0.010 s
Std Dev of the mean	0.008 s	Std Dev of the mean	0.014 s
Observation Time	10 s	Observation Time	900 s

Timing Bias (corrected for Start / Stop Time Delay)	0.048 s
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Stopwatch Pushbutton Characteristics

Soft-operating	Hard-operating
produces negligible start / stop delays	produces appreciable start / stop delays
produces consistent timing operation	produces inconsistent timing operation



Stopwatch Calibrator is able to distinguish timing bias caused by the start / stop time delays from the stopwatch time base running fast or slow

Uncertainty Estimates

- 900 s observation time
- Stopwatch with 'soft-operating' start/stop push button switch

<i>Source of Uncertainty</i>	<i>Uncertainty Value</i>	<i>Distribution Factor</i>	<i>Combined Uncertainty</i>
<i>Start/Stop Delay Measurement</i>			
<i>Frequency Standard</i>	4.50E-10 s	2	2.25E-10 s
<i>Counter Gate Opening</i>	0.00005 s	1.7321	2.89E-05 s
<i>Counter Gate Closing</i>	0.00005 s	1.7321	2.89E-05 s
<i>ESDM of Delay Time</i>	0.0043 s	1	4.28E-03 s
<i>Stopwatch Resolution</i>	0.005 s	1.7321	2.89E-03 s
<i>Time Offset Measurement</i>			
<i>Frequency Standard</i>	4.50E-10 s	2	2.25E-10 s
<i>Counter Gate Opening</i>	0.00005 s	1.7321	2.89E-05 s
<i>Counter Gate Closing</i>	0.00005 s	1.7321	2.89E-05 s
<i>ESDM of Time Offset</i>	0.006 s	1	6.06E-03 s
<i>Stopwatch Resolution</i>	0.005 s	1.7321	2.89E-03 s
<i>Combined Uncertainty</i>			0.008469 s
<i>Expanded Uncertainty</i>			0.017 s

Conclusion

-  An operator reaction time-free Stopwatch Calibrator has been developed
-  Any remaining switch timing differences are eliminated by the time differencing operations thereby enhancing the accuracy obtained from the calibration
-  The calibration setup is able to determine any appreciable Stopwatch start / stop pushbutton time delay; allows for corrections, if necessary, thereby enhancing measurement accuracy
-  Calibration setup simulates operations during use; reveals and accounts for errors otherwise not covered by other methods
-  Start / stop delays and non-synchronization are independent of the operator; may be used by even unskilled technicians in secondary calibration laboratories

References

- Stopwatch and Timer Calibrations, National Institute of Standards and Technology, USA Special Publication 960-12, May 2004
- Testing Times, Tim Armstrong, Measurement Matters, Automation & Control, August - September 2004
- Stopwatch and Timer Calibrations with Internet Reference Signal, J. Horský, Czech Calibration Society and J. Horská, Czech Metrology Institute, 7.02.2013



Thank you for your kind attention!



