UNIVIB & AMTRI INTERVAL TIMER SYSTEMS

GUIDANCE NOTES FOR EXTERNAL TEST AND CALIBRATION COMPANIES

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1. Introduction

UNIVIB supplies the UNIVIB Interval Timer system for the measurement of the stopping times of machinery fitted with light curtain guarding systems. UNIVIB also supports the AMTRI Interval Timer system, the predecessor to the UNIVIB system.

These notes are provided for the benefit of those persons charged with the task of testing and checking the calibration of these systems, for example, the staff of external test and calibration companies. The notes are applicable to both UNIVIB and AMTRI Interval Timer systems. It is assumed that the reader has access to the User Handbook that has been issued with each system which explains how the system is set-up and used in practice.

The UNIVIB Interval Timer system should be subject to test on a regular basis to:

(1) verify the correct operation of the system.
(2) check whether the calibration and measurement uncertainty associated with the system continues to be within specification.

As stated in Section 9 of the User Handbook, the recommended period between each test and calibration check is 12 months (unless any part of the system is subjected to possible damage, in which case the whole system should be re-tested before it is used again).

The calibration of the system is not adjustable by the user or by external calibration companies. If the results of the system test indicate that the measurement uncertainty of the system is no longer in accordance with that specified in Section 10 of the User Handbook, then the system should be returned to UNIVIB for inspection and, if necessary, re-calibration or repair.

2. Brief Description of Operation

The mechanical finger supplied with the system is used to break the beam of a light-curtain guarding system, thereby initiating an emergency stop of the machinery under test. The “start timing” trigger is generated by the change of state of the contacts of a switch mounted inside the mechanical finger. In practice, the mechanical finger needs to be carefully mounted so that the light beam is broken (and hence the emergency stop initiated) as nearly as possible simultaneously with the change of state of the switch contacts (and hence the start of timing).

The draw-string encoder motion sensor is used to measure the motion of reciprocating machinery such as presses and guillotines, producing a “stop timing” trigger when either the speed of motion falls below a pre-set threshold, or when the direction of motion changes (see Section 3 on page 4 for more details).

The Interval Timer measures the elapsed time between the “start” and “stop” triggers.

A pressure pad start trigger has also been supplied to some users so that the system can be used to measure the stopping time when an emergency stop button is used to initiate the emergency stop.

A rubber-tyred measuring wheel encoder motion sensor is also available and has been purchased by some users. This allows the system to measure the stopping times of machinery involving continuous linear or rotary motion, such as that of a conveyor belt or a roller driving a conveyor system, for example.

3. Criteria Used to Stop the Timing Process

Applicable to all UNIVIB systems and all AMTRI systems except those with serial numbers: 0202, 0206, 0207, 0210, 0211 and 0215

The system stops timing when **either:**

(a) the speed of motion reduces to 400 mm/min or less (applicable to machines that decelerate smoothly to rest), **or**

(b) the direction of motion changes (applicable to machines with auto return-to-park facility, or to machines that oscillate (“bounce”) before coming to rest because of residual oscillation, or wind-up, of the drive at the end of the deceleration, or transient vibration of the machine frame occurring as a result of the sudden deceleration, for example).

Most of the data-processing is carried out inside the timer display unit. Here, the processor is programmed to measure the time period between adjacent edges of the pulse train from the encoder. As the machine decelerates the time between adjacent edges increases. When it exceeds a certain pre-set value (corresponding to a speed of around 400 mm/min) timing ceases.

The detection of a change in the direction of motion of the machine is carried out by a small processor circuit located inside the cover of the draw-string encoder unit (in the case of the measuring wheel encoder, the circuit is contained in the little white box built into the connecting cable). If, at any time, this circuit detects that the direction of motion has changed then it withholds the pulse train from the encoder for a short period (greater than the pre-set value) which then causes the timer to cease timing as explained in the preceding paragraph. If no such reversal is detected the circuit simply passes the encoder pulse train through to the timer display unit.

The motions of relatively massive and stiff machines (such as the traverse of the axes of machine tools, for example) are more likely to decelerate smoothly to rest than smaller, more flexible machines (such as guillotines, for example). These latter are more likely to stop suddenly with a direction reversal (or bounce) at the end of travel caused by wind-up and release of the drive, or other vibrations. Because of the inherent way in which the Interval Timer system works, the measurement uncertainties associated with the results it yields will be different if the system is used to make measurements on machines that decelerate smoothly to rest (with no reversals) than they will be if it is used to measure machines that stop more suddenly with a reversal, or bounce, at the end of travel. The nature of these differences is explained below:

If the Interval Timer system is used to make repeated measurements on a “perfectly repeatable” machine that decelerates smoothly to rest then UNIVIB’s tests have shown that the errors associated with the measurement results produced by the system are likely to be as follows:

- the *mean* of the measured deviations will be positive (meaning the timer is indicating a longer-than-actual time) and will typically be around + 5 msec.
- the 6-sigma band will be upto 20 msec.

If the Interval Timer system is used to make repeated measurements on a “perfectly repeatable” machine that stops more suddenly with a “bounce” at the end of travel then, in this case, UNIVIB’s tests have shown that the errors associated with the measurement results produced by the system are likely to be as follows:

- the *mean* of the measured deviations will be negative (meaning the timer is indicating a shorter-than-actual time) and will typically be around - 1.5 msec.
- the 6-sigma band will be upto 5 msec.

These differences in the degree and nature of the uncertainty of measurement are associated with the inherent manner in which the timer system works. It is anticipated by UNIVIB that, for the most part, the systems will be used to measure machines that stop suddenly and with a “bounce” at the end of travel so the measurement uncertainties will generally be in accordance with the lower of the above estimates. To accommodate both possible scenarios above, however, a particularly conservative approach has been taken by UNIVIB and the publicised measurement uncertainty associated with the system is quoted “officially” as ± 20 msec. In reality, however, for the majority of test situations it is likely to be considerably better than this.

> Note that the figures mentioned above have been derived from extensive testing carried out by both AMTRI and UNIVIB. However, they can only ever be estimates because, in reality, it is impossible to create a “perfectly repeatable” test machine or test-rig. This means that it is inevitable that the scatter in the results of any set of tests is always made up of an *inseparable contribution* of errors arising from the effects of non-repeatability of the test machine or test-rig and errors arising from the effects of non-repeatability of the measuring system itself. This is, of course, true for any measuring system, not just the Interval Timer!

Applicable to AMTRI systems with serial numbers: 0202, 0206, 0207, 0210, 0211 and 0215

These early AMTRI systems did not incorporate the facility for the detection of reversals in the direction of motion so, in these cases, the system simply stops timing when **the speed of motion reduces to 400 mm/min or less**, irrespective of whether any changes in the direction of travel occur. This means that the measured times are likely to be slightly longer and the scatter of the results likely to be greater than those of the later systems - because the systems will continue to time until the magnitude of the vibrations (bounces) at the end of travel drops below a certain threshold.

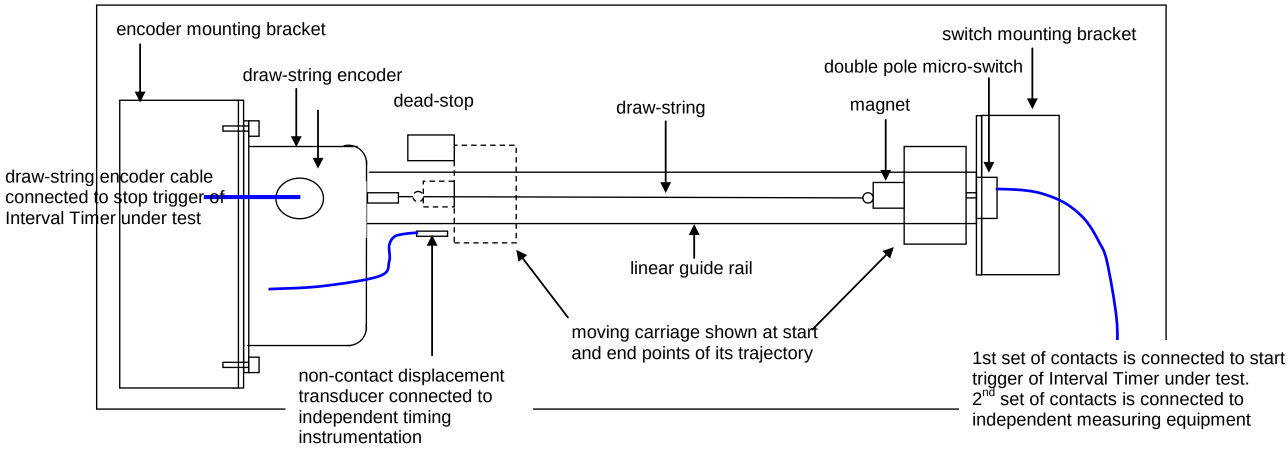
4. UNIVIB’s Procedure for Test and Calibration of the Systems

During its initial set up prior to supply to the customer, testing and calibration of the UNIVIB Interval Timer system is carried out by UNIVIB in two stages.

The first stage involves checking the basic accuracy and repeatability of the timer itself without any of the supplied accessories attached. This involves using simple switch closures to provide both the start and the stop triggers and comparing the results against a reference timer triggered, simultaneously, in the same manner. The results of this procedure are used to check that (1) the basic timer system inside the display unit is working correctly and that (2) its inherent accuracy is within UNIVIB's internal specification requirements.

The basic calibration of the timer is factory set by UNIVIB prior to delivery of the system to the customer. Experience has shown that once this calibration has been initially set, the stability of the crystal oscillator used in the timer circuit is such that it should normally never again need to be adjusted. The calibration adjustment process is, therefore, not accessible to anyone other than UNIVIB Ltd. In the extremely unlikely event that the calibration or measurement uncertainty of a system is ever found to be outside specification then the system should be considered faulty and should be returned to UNIVIB for inspection and repair.

The second stage of the test and calibration process involves the use of a test-rig so that the time-of-flight of a moving carriage can be measured by both the timer and by an independent timing system, simultaneously, and the results compared. The diagram below shows the major components of the test rig used by UNIVIB to test and check the performance of the systems



The test rig comprises a short length of linear guide rail mounted to a board, along which a small carriage mounted to a linear guide bearing block is able to move freely. The draw-string encoder of the system under test is mounted to a bracket at one end of the track. Its magnet is attached to the moving carriage. To begin with, the moving carriage is held, by hand, firmly against a micro-switch mounted at the other end of the track, so that the switch contacts are closed. The Interval Timer and the independent timing instrument are both armed. The carriage is then released so that the switch contacts open - starting the timing process in both the Interval Timer and in the independent measuring system. (By using a double pole micro-switch both the Interval Timer and the independent timing instrument are triggered as nearly simultaneously as possible to start timing).

The carriage is allowed to move in a controlled manner along the track with the return spring inside the encoder providing the motive force until it hits a dead-stop, at which point the timing process in the Interval Timer is stopped. A non-contact capacitive displacement transducer is mounted close to the dead-stop and is used to detect the arrival of the carriage at the dead-stop. The change of direction that occurs as the carriages bounces slightly away from the dead-stop is detected by monitoring the signal from the displacement transducer using a dynamic signal analyser set up in time-history capture mode. The time indicated by the analyser at which this change of direction occurred is used to provide an independent determination as to when the motion “ceased”.

The times-of-flight of the carriage measured by the Interval Timer and by the independent measuring instrument are compared. At least 10 repeat measurements are made and a statistical analysis of the results is carried out in a spreadsheet. A typical set of results is shown below (all results are recorded in the table in seconds and have been rounded to the nearest millisecond):

Reference Timer	Interval Timer	Measured Deviation
0.638	0.637	-0.001
0.757	0.757	0.000
0.615	0.614	-0.001
0.700	0.699	-0.001
0.644	0.641	-0.003
0.733	0.731	-0.002
0.671	0.670	-0.001
0.730	0.728	-0.002
0.790	0.788	-0.002
0.668	0.667	-0.001

Statistical analysis on the above data gives:

mean deviation = - 0.0014 sec
3xsigma = 0.0025 sec
(mean + 3xsigma) = 0.0011 sec
(mean – 3xsigma) = - 0.0039 sec.

The above data is taken from the test results of one example of a timer system. The deviations recorded when checking other systems are, in most cases, of a similar nature, with the measured deviations usually lying in the range 0 to – 0.003 sec, as in the above example.

When testing a system in conjunction with a measuring wheel encoder a similar test set-up is used. However, the fixed track is replaced with a moving track which is positioned and oriented so that it turns the wheel of the (fixed) encoder. The nature, magnitudes and range of the measured deviations should be similar to those recorded with the draw-string encoder set-up.

5. Important Considerations about the Test Procedure for External Calibration Companies

The calibration of the system is not adjustable by the user or by external calibration companies. If the results of the system test indicate that the measurement uncertainty of the system is no longer in accordance with that specified in Section 10 of the User Handbook, then the system should be returned to UNIVIB for inspection and, if necessary, re-calibration or repair.

The procedure used to test the Interval Timer system **must involve testing the Interval Timer display unit and the draw-string encoder motion sensor together as a complete system** and so the test-rig used to carry out these tests must facilitate this**.** This is because there is a small processor board under the cover of the encoder motion sensor in which part of the decision-making process about whether the machine under test has stopped moving or not is carried out. So the encoder **must** be included as an integral part of the system under test.

If the system also includes a measuring wheel encoder motion sensor, a repeat set of tests should be carried out with this encoder connected to the Interval Timer in place of the draw-string encoder, the test-rig having been modified accordingly to accommodate the measuring wheel encoder. As before, the procedure used to test the Interval Timer system **must involve testing the Interval Timer display unit and the measuring wheel encoder motion sensor together as a complete system.**

Testing and checking the timer display unit in isolation is **not** to be considered an adequate test of the system.

The start of timing of both the Interval Timer system and the independent measuring system should be initiated by monitoring the change of state of either the switch inside the mechanical finger or a suitable alternative switch. In either case, care must be taken to ensure that the start of timing of the Interval Timer system and that of the independent measuring system are triggered as nearly simultaneously as is possible. The following section provides helpful information in this respect.

6. Start Trigger Connection Details

The table below shows how the connections have been made for the start trigger cable (ie: the integral cable that connects the mechanical finger to the Interval Timer display unit).

Name	Wire colour	Connection at Binder plug	Connection at mechanical finger
Trigger +V	Green	Pin 1	one side of switch
Trigger sense	White	Pin 2	other side of switch
Supply 0V	Screen	Pin 7	not connected

Note: (1) the "polarity" of the connections at the switch contacts inside the mechanical finger is unimportant.
(2) Pin 6 (trigger type) is linked to Pin 7 (Supply 0V) at the Binder plug. (This provides an indication to the timer about the type of start trigger that is connected).

Plug at Interval Timer end of cable
Binder sub miniature cable-mount connector, series 712, 7-way, (Farnell 112-2554 or RS 115-2770).

Cable
FS Cables, LIYCY colour coded, 5 x 0.14 sq. mm, part no. 32000105F.

If the mechanical finger is not used to trigger the start of timing and, instead, an alternative switch is to be used, then connect its contacts to pins 1 and 2 at the Binder plug (polarity not important) and link pins 6 and 7 inside the Binder plug. If the cable incorporates a screen, this should be connected to pin 7 at the Binder plug and to earth at the switch-end of the cable.

Note that the Interval Timer will commence timing when it detects either an opening or a closing of the switch contacts, so it does not matter whether a normally open or normally closed switch is used.

For further information please contact UNIVIB (contact details are given on the front cover of this document).