METRO LAB

Instrument S.A.

PDI 5025

FAST MEASUREMENT OF MAGNETIC FIELD CYCLES

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Fast measurement of repetitive magnetic cycles using the METROLAB PDI 5025 Precision Digital Integrator

The METROLAB PDI5025 Precision Digital Integrator can perform measurements of fast and repetitive time varying magnetic field cycles such as the gradient fields in Magnetic Resonance Imaging systems and the accelerator pulsed magnets. Although the PDI5025 requires a minimum time interval of 1 ms between triggers, the measurements can be performed at **10 μs** time rate using a sliding sampling method ("stroboscopic" effect).

We assume that the phenomenon to be measured is periodically repeated and there is a synchronization signal at each cycle giving reproductive timing. The trigger sequence, repeated over several consecutive events, is slided by a certain amount of time at each synchronization signal with a slide step being only a fraction of the trigger interval. After the integrator PDI5025 has recorded the events, the host computer superimposes them in a way to obtain one event. In this case the measurement interval is equal to the slide step which can be much smaller than the trigger interval. Since the measuring process is not interrupted between events, all triggers, including the first one at or following the synchronization signal, give a significative measurement. The time slide and the number of events to record are programmed as parameters to the integrator PDI5025. The time slide can be incremented by step as small as **10 μs**; the trigger timer has a resolution of 1 ms. Using this method it is possible to obtain 100 times more measurements of the phenomenon under investigation than with the normal PDI5025 operation. The integrator uses the synchronization signal as time reference for each event and does not need to know the period between events. However, this information is needed to correct the drift accurately (see below).

There are two possibilities for sliding the trigger sequence:

a) Shift from synchronization signal (SSY)

The first trigger at or following the synchronization signal is delayed by an amount of time increasing at each event. The full trigger sequence is shifted by the same amount of time while the integration intervals are not modified.

See pages 3 and 4 and figures 1 and 2.

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b) Increment first trigger interval (IFT)

The first trigger of the sequence (trigger 0) is not moved and the second one (trigger 1) is delayed by an amount of time increasing at each event. The following triggers keep the same timing relative to trigger 1 and are shifted from the synchronization signal by the same delay as trigger 1. The first integration interval increases at each event while the other ones are not modified. Therefore, the first trigger at or following the synchronization signal is identical for all events.

See pages 5 and 6 and figures 3 and 4.

Though there are some differences, the user can use both methods equally well. The first one allows fine investigation from the synchronization signal while the second one can be more appropriate if an overrange condition occurs (see below).

The cumulated (total flux change) or individual (flux change from previous trigger) values are available from the integrator PDI5025. The individual values are the flux changes over the integration time interval, which can not be smaller than 1 ms. Even after rearrangement they still represent a variation over 1 ms or longer and are not equivalent to a fast measurement. This is not the case with cumulated values which give the total flux change at trigger time from the start point. Interlacing cumulated values is equivalent to a faster measuring rate.

In order to correct the data for the drift of the integrator, it is preferable to program sliding parameters in such a way that at least two events overlap partially, e.g. the first and the last one. In this case pairs of points have the same time relative to the synchronization signal and their difference is interpreted as due to the drift. To have an accurate correction of the drift, it is necessary to know the period between synchronization signals since the drift is proportional to the acquisition time (see figures 5 and 6).

If the phenomenon to be investigated involves a wide range of induced voltages, the low signal region can be measured with a higher sensitivity (gain) by programming the PDI5025 in such a way that the trigger sequence starts or stops before the high signal region. In this way the gain can be increased and the overrange condition, if any, occurs outside the region of measurement. The continuity of the measurement is broken by the overrange condition and the events are no longer related to each other. In this case the IFT method is certainly more suitable since it gives a common point in all events. This common point is used to link events together.

Shift from SYnchronization signal (SSY)

TRI,,a/n,c : a = time of start (resolution 10 μs)
n = number of triggers
c = integration interval (resolution 1 ms)

SSY,N,D : N = number of events
D = time increment (resolution 10 μs)

Original order :

trigger #	$t_{rel\ synch}$ =	
	0	<--- synch. signal
0	a	
1	a+c	
2	a+2c	
.	.	
.	.	
n	a+nc	
	0	<--- synch. signal
n+1	a+D	
n+2	a+c+D	
n+3	a+2c+D	
.	.	
.	.	
n+1+n	a+nc+D	
	0	<--- synch. signal
2n+2	a+2D	
2n+3	a+c+2D	
2n+4	a+2c+2D	
.	.	
.	.	
.	.	
2n+2+n	a+nc+2D	
	0	<--- synch. signal
.	.	
.	.	
.	.	
	0	<--- synch. signal
(N-1)(n+1)	a+(N-1)D	
(N-1)(n+1)+1	a+c+(N-1)D	
(N-1)(n+1)+2	a+2c+(N-1)D	
.	.	
.	.	
.	.	
N(n+1)-1	a+nc+(N-1)D	

rearranged order (SSY):

original trigger #	$t_{rel\ synch}$ =	
	0	<--- synch. signal
0	a	
n+1	a+D	
2n+2	a+2D	
.	.	
.	.	
(N-1)(n+1)	a+(N-1)D	
1	a+c	
n+2	a+c+D	
2n+3	a+c+2D	
.	.	
.	.	
(N-1)(n+1)+1	a+c+(N-1)D	
2	a+2c	
n+3	a+c+D	
2n+4	a+2c+D	
.	.	
.	.	
(n-1)(n+1)+2	a+2c+(N-1)D	
.	.	
.	.	
.	.	
n	a+nc	
n+1+n	a+nc+D	
2n+2+n	a+nc+2D	
.	.	
.	.	
N(n+1)-1	a+nc+(N-1)D	

Increment First Trigger interval (IFT)

TRI,,a/n,c : a = time of start (resolution 10 µs)
n = number of triggers
c = integration interval (resolution 1 ms)

IFT,N,C : N = number of events
D = time increment (resolution 10 µs)

Original order :

	$t_{rel\ synch} = 0$	<--- synch. signal
trigger # 0	a	
1	a+c	
2	a+2c	
.	.	
.	.	
n	a+nc	
		<--- synch. signal
n+1	a	
n+2	a+c+D	
n+3	a+2c+D	
.	.	
.	.	
n+1+n	a+nc+D	
		<--- synch. signal
2n+2	a	
2n+3	a+c+2D	
2n+4	a+2c+2D	
.	.	
.	.	
.	.	
2n+2+n	a+nc+2D	
		<--- synch. signal
.	.	
.	.	
.	.	
		<--- synch. signal
(N-1)(n+1)	a	
(N-1)(n+1)+1	a+c+(N-1)D	
(N-1)(n+1)+2	a+2c+(N-1)D	
.	.	
.	.	
.	.	
N(n+1)-1	a+nc+(N-1)D	

rearranged order (IFT):

original trigger #	$t_{rel\ synch} = 0$	<--- synch. signal
0	a	
n+1	a	
2n+2	a	
.	.	
.	.	
(N-1)(n+1)	a	
1	a+c	
n+2	a+c+D	
2n+3	a+c+2D	
.	.	
.	.	
(N-1)(n+1)+1	a+c+(N-1)D	
2	a+2c	
n+3	a+c+D	
2n+4	a+2c+D	
.	.	
.	.	
(n-1)(n+1)+2	a+2c+(N-1)D	
.	.	
.	.	
.	.	
n	a+nc	
n+1+n	a+nc+D	
2n+2+n	a+nc+2D	
.	.	
.	.	
N(n+1)-1	a+nc+(N-1)D	

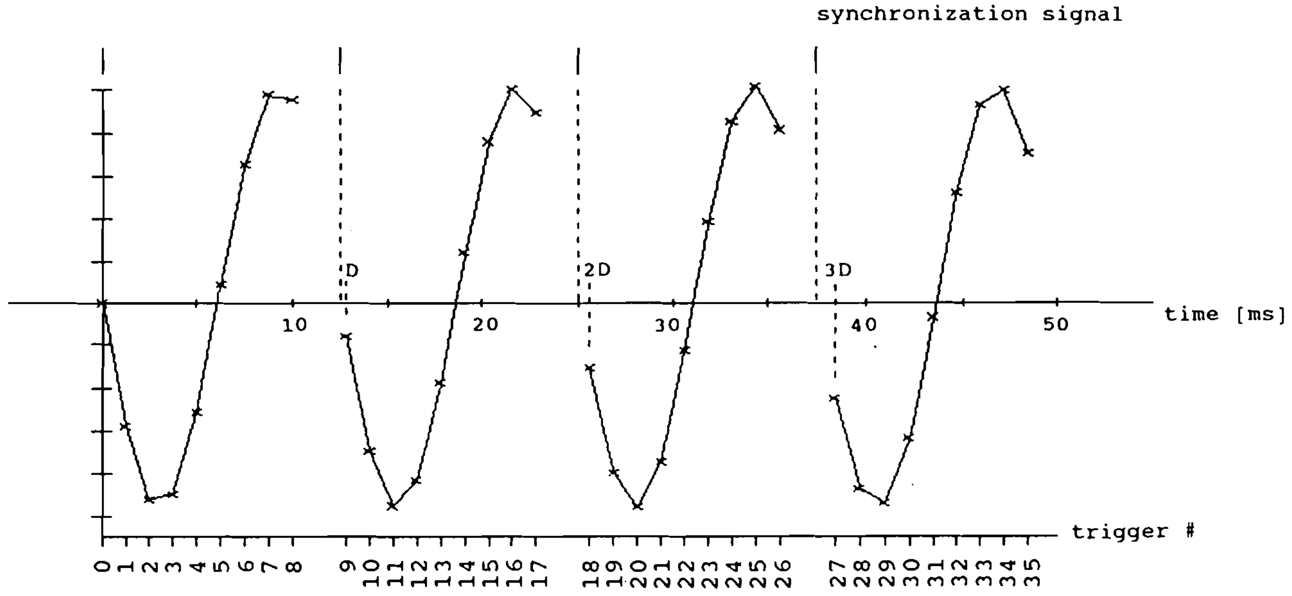

Figure 1 : Shift from SYnchronization signal (SSY),
Original order,
TRI,,0/8,1ms - SSY,4,250µs

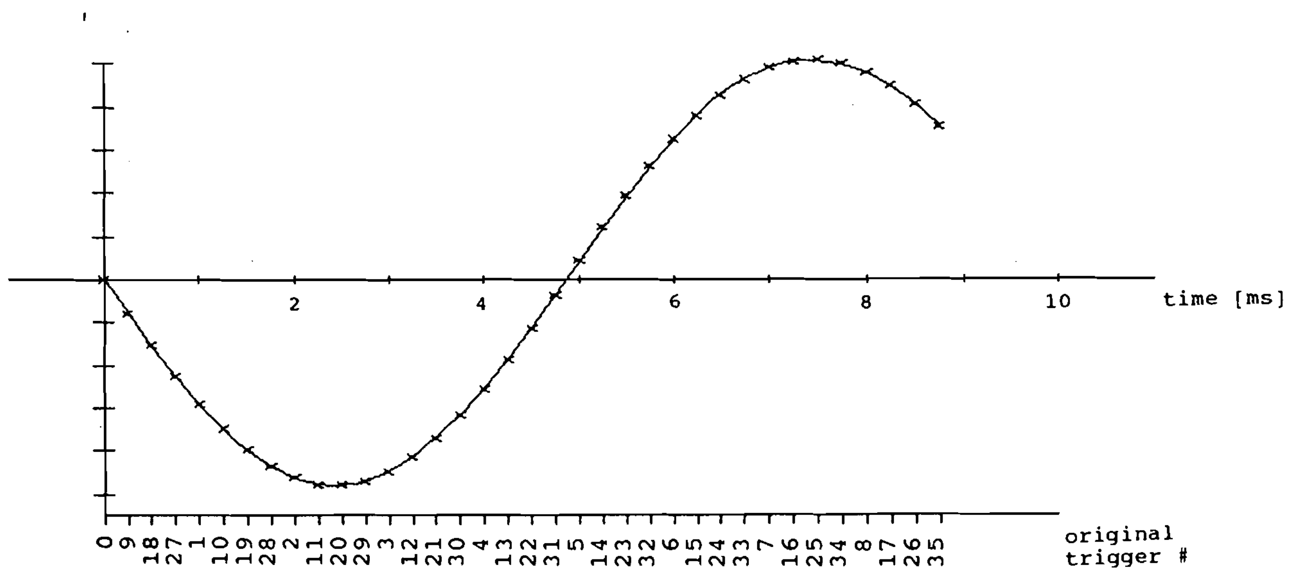

Figure 2 : Shift from SYnchronization signal (SSY),
Rearranged order,
TRI,,0/8,1ms - SSY,4,250µs

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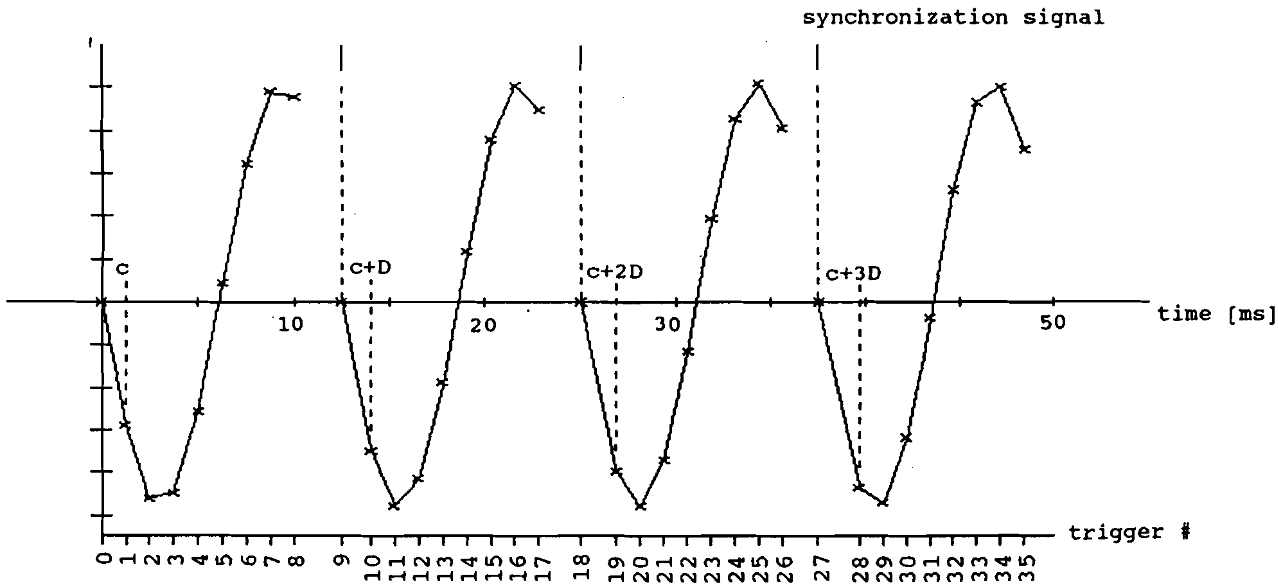


Figure 3 : Increment First Trigger interval (IFT),
Original order,
TRI,,0/8,1ms - IFT,4,250µs

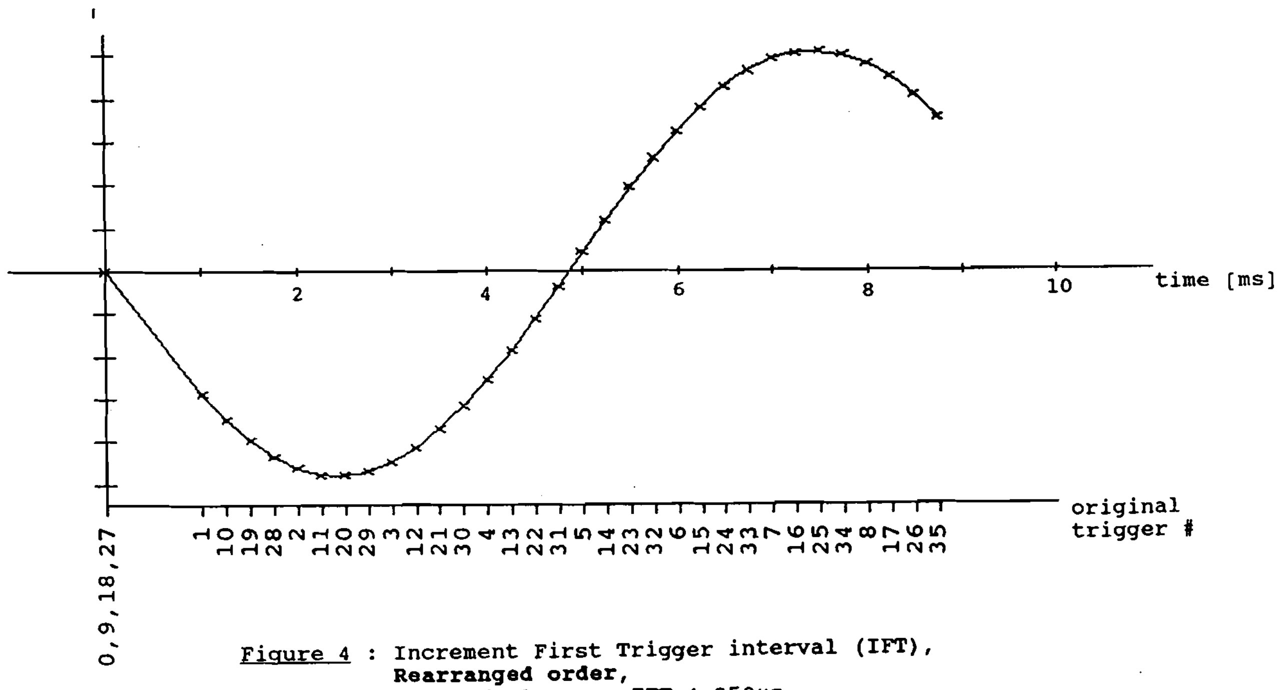
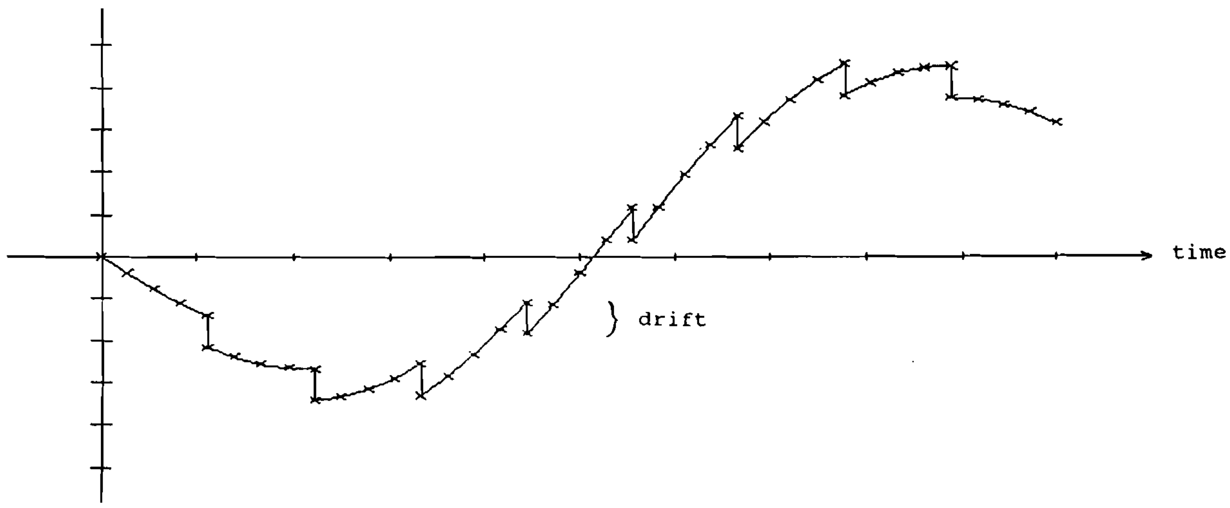
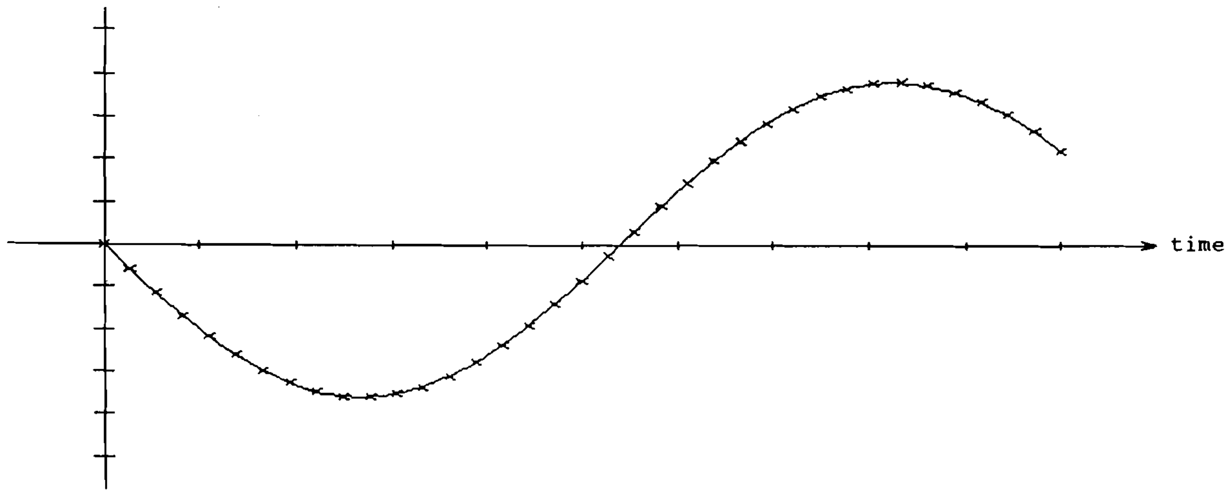


Figure 4 : Increment First Trigger interval (IFT),
Rearranged order,
TRI,,0/8,1ms - IFT,4,250µs



<u>Figure 5</u> : Shift from SYnchronization signal (SSY),
Rearranged order,
before drift correction.



<u>Figure 6</u> : Shift from SYnchronization signal (SSY),
Rearranged order,
after drift correction.