Synchronized vs. Sequential sampling methods for measurement systems – effects on the system structure

White Paper

By Prof. Dr.-Ing Klaus Metzger

How does one select the right measurement system structure for a given measurement task? Should channels be sampled simultaneously, in synchronization, or is it sufficient for the channels to be sampled sequentially using an analog multiplexer? Anyone making multichannel measurements is confronted with this issue.

Examples of the effect sampling method has on measurement results

To illustrate the issues, we consider several measurements. To determine the instantaneous electrical power p(t), we multiply the values for the voltage u(t) and the current i(t) as p(t) = [u(t) i(t)]. The formula states that the corresponding instantaneous voltage and current values are to be multiplied.

If these quantities are sampled by a measurement system at times 0, T, 2T, 3T,..., then the formula may be interpreted as stating that simultaneous pairs of the streaming current and voltage values must be recorded and multiplied with each other.

The non-simultaneous sampling method with multiplexer timing is illustrated in the graph below. If the Channel 1 (Ch_1) is sampled at time T, the second channel Ch_2 is captured at the next sampling time 2T. This alternating sampling pattern repeats continuously. Examining the sample at any particular time, for instance, 2T, it is seen that there is a sampled value for Ch_2, but not for Ch_1. Consequently, the computations described above cannot be performed, since we do not possess values from both channels at the same instant in time.

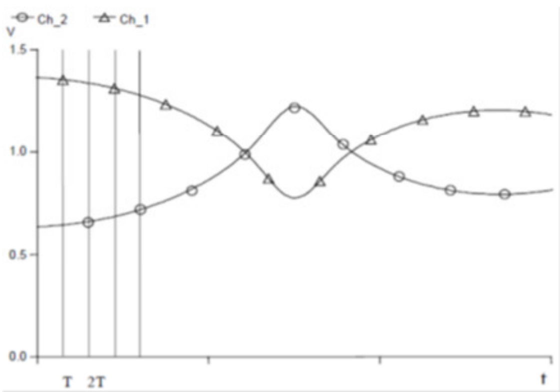


Figure 1: *Signal sampling of two channels with multiplexer timing. The vertical lines denote the sampling times T, 2T etc. Each one of the channels is sampled alternately.*

This example serves to further illustrate the difficulties involved with multiplexer-timed sampling:

Consider this same measurement with the sampling frequency 10 kHz (10,000 measurements per second), which is to capture our two sinusoidal signals, one of current and of voltage, each having a 50 Hz signal frequency (20 ms period duration) (note: typically 50 Hz signals are only sampled at 200 or 500 Hz!). The time offset between the sequential samples, only 100 µs (T = 1/10 kHz = 100 µs), corresponds to a phase shift of 1.8°, since 20 ms represents a full cycle of 360°.

However, such a small phase shift may be critical, as it can well be in electronic engineering: in the measurement of the reactive power, then the offset between sampling times may cause the relative error in the reactive power, which is almost proportional to the angle offset, to become virtually unlimited in scale.

As even this little example shows, the capture of the two channels must be absolutely synchronized.

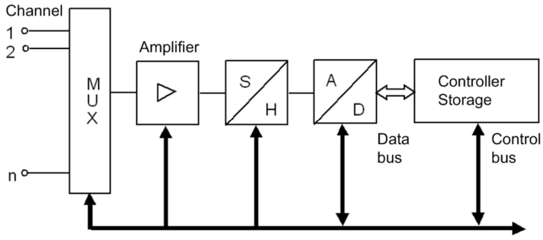
Although multiplexed systems tend to be smaller, lower power, and less expensive, the question arises of when, or if, multiplexer-timed sampling is ever technically avantgeous? It is a sensible approach, if the measured quantities do not need to be combined with each other in mathematical operations, or if their mutual relationship in time is not relevant.

An example of this latter case: If measurements of the stresses on mechanical parts are performed (class-counting method), the time relationships are of no importance. For instance, if a piece of steel sheet is subjected to bending, it plays no role when this happened, only that it did. Such parameters as the maximum extent of the bending are decisive. Here, synchronized sampling is not at all necessary.

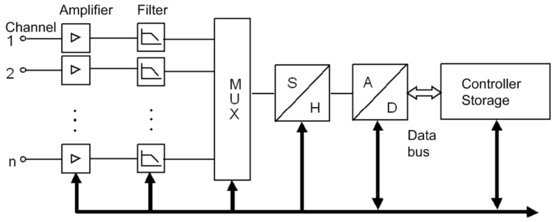
Measurement System Structures

The discussion below presents the common structures of measurement systems, capable of either synchronized or nonsynchronized sampling. The suitability of the different designs for a variety of measurement tasks is explored.

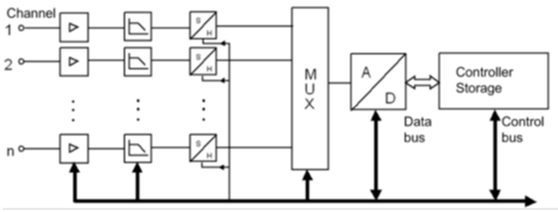
The following figure shows the basic measurement system structures:



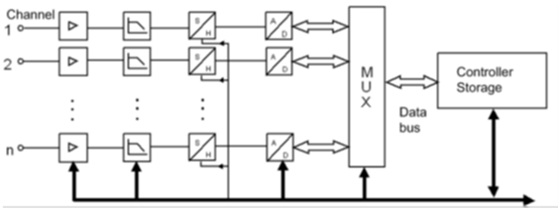
a) analog multiplexing of measurement channels without individual channel amplification; time-offset channel sampling



b) analog multiplexing of measurement channels; time-offset channel sampling



c) analog multiplexing of measurement channels; simultaneous channel sampling



d) digital multiplexing of measurement channels; simultaneous channel sampling

At the "front end," a measurement system generally consists of amplifiers for adapting a sensor's signal to the electronic instruments into which it is fed. A filter (anti-aliasing filter) serves to eliminate from the measurement signal any component frequencies higher than one-half of the sampling frequency (refer to the White Paper on the Sampling Theorem).

The Sample-and-Hold amplifier (S/H) holds the voltage prevailing at the instant of the sampling until the AD-converter has transformed the analog measured value into its digital representation. The control lines to the S/H amplifier, seen in Figures c) and d), ensure that the channels' signals are captured simultaneously. Since under d) every channel comes with its own AD-converter, such systems allow higher aggregate sampling rates than system following the c) scheme.

The solutions shown in a) and b) are used in simple systems (e.g., in PC plug-in boards) due to their low cost and compact design. However, they have decisive drawbacks when compared to the other systems, stemming from the multi-plexing of the signal inputs, which precludes any computational processing of the measurement signals.

Since in this scheme, the measurement signal is only amplified after the multi-plexer, all of the multi-plexer's error is amplified and superimposed on the signal.

Further, filtering of the signals in circuit a), following the multi-plexer, is technically difficult: each time the multi-plexer switches to a channel, there is a delay until the filter's transients subside and the AD-conversion can take place.

Whether simultaneous signal capture is necessary depends on the application, as previously noted. At imc, processes were developed which enable synchronized sampling even with systems structured as in a) and b). Measured values are computed by digital signal processors online according to interpolation procedures, so that here, too, synchronized data capture is possible (e.g., the power measurement). Examples of this include the scanner systems such as the imc CRONOS-PL's SC-32 or the imc CANSAS SC16.

Most systems produced by imc work according to the system structure of d), achieving the highest levels of signal quality.

Additional information:

imc Test & Measurement GmbH
Voltastr. 5
13355 Berlin, Germany

Telephone:	+49 (0)30-46 7090-0
Fax:	+49 (0)30-46 31 576
E-mail:	hotline@imc-tm.de
Internet:	http://www.imc-tm.com

imc Test & Measurement GmbH is a manufacturer and solution provider of productive test and measurement systems. imc implements metrological solutions for research, development, service and production. imc has particular expertise in the design and production of turnkey electric motor test benches. Precisely outfitted sensor and telemetry systems complement our customer applications.

Our customers from the fields of automotive engineering, mechanical engineering, railway, aerospace and energy use imc measurement devices, software solutions and test stands to validate prototypes, optimize products, monitor processes and gain insights from measurement data. As a solution provider, imc offers their customers an attractive and comprehensive range of services. These include project consulting, contracted measurements, data evaluation, specialist deployment, customer-specific software development and system integration. imc consistently pursues its claim of providing services for “productive testing”.

If you would like to find out more specific information about imc products or services in your particular location, or if you are interested in becoming an imc distributor yourself, please go to our website where you will find both a world-wide distributor list and more details about becoming an imc distributor yourself:

http://www.imc-tm.com/our-partners/