

# Measuring currents in drive technology with microcontrollers

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The contribution that must be made by energy-efficient drives for the energy revolution is indisputable. It is not just a case of having the best technical solutions when doing this, but also having solutions that can be achieved cost-effectively. As far as the development cost of a drive controller is concerned, it is not just component costs that have to be taken into consideration. In an increasing number of cases the development costs and particularly the cost of the software must be considered. For this reason a manufacturer will think carefully about when to use a specific optimized controller and when to use a standard solution. It would be desirable to have a modular construction kit concept that meets the various requirements.

The manufacturers of frequency converters often cover a wide range of different performance and voltage classes and applications. This is exactly why Infineon has developed the XMC4000 32-bit microcontroller family.



An important part of a frequency converter is the current measurement, which is the basis for the control. Measuring errors are difficult to detect, and propagate themselves throughout the entire control algorithm. The accuracy of the current measurement ultimately determines the efficiency level and performance of the drive. This article explains what current measuring options the XMC4500 opens up for engineers in their industrial and motor control designs.

### The signal characteristics

The direct phase current measurement provides a continuous bidirectional signal. In the figures on the following page, (A and B in fig. 2), the emitter path provides a pulse-shaped bidirectional signal (C in fig. 2) and the negative intermediate circuit provides a unidirectional pulsed signal (D in fig. 2a). Only the direct phase current measurement provides the actual currents of the motor at any point in time--all other methods have restrictions.

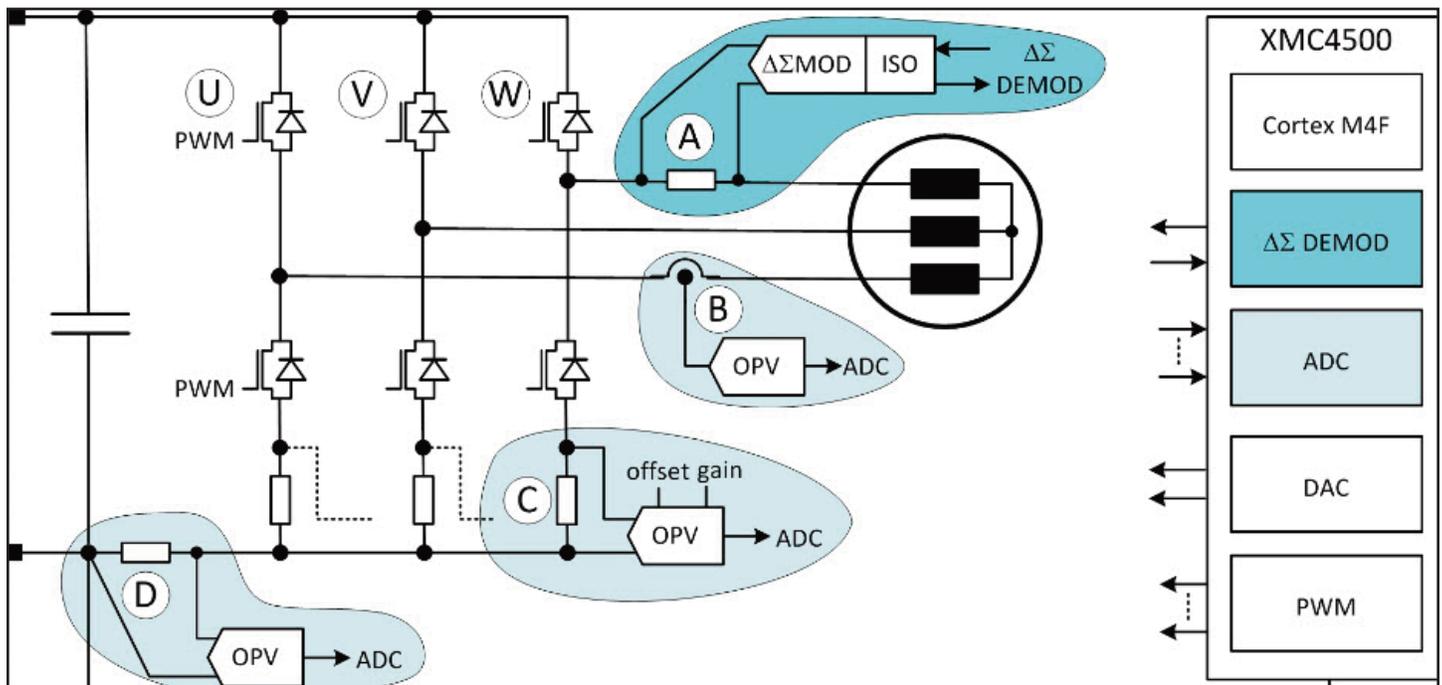


Figure 1: Frequency converter with various facilities for measuring current using a microcontroller

### The measuring location

Depending on the application, output and performance, there are different ways of determining the current of a motor (see Fig. 1). The complexity of the measurement depends on the location. A directly measured phase current (point A or B in fig. 1) requires a potential-free measurement, whereas the currents in the emitter path or in the negative intermediate circuit (points C and D in fig. 1) have the same earth reference as the MCU.

With high-value applications such as servo motors and higher output classes (several kilowatts), the phase current measurement is normally used, whereas the emitter path measurement is normally used for the "General Purpose" area.

The measurement in the negative intermediate circuit is used in "Consumer" drives or for sensor-less emergency running. (Fig. 2a, 2b, 2c)

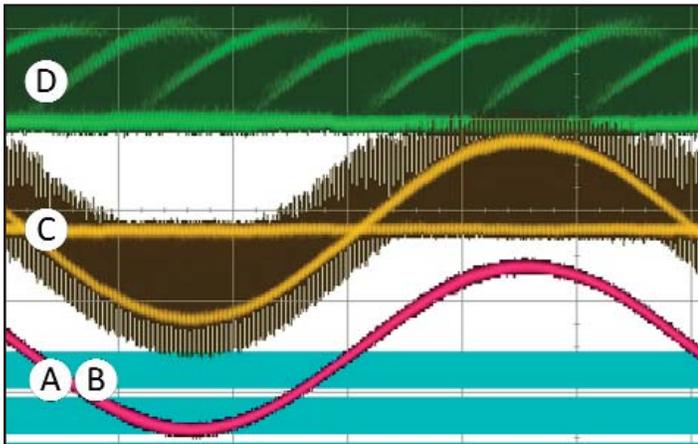


Figure 2a: A and B direct phase current, C emitter current, D intermediate circuit current; Resolution 5ms/div

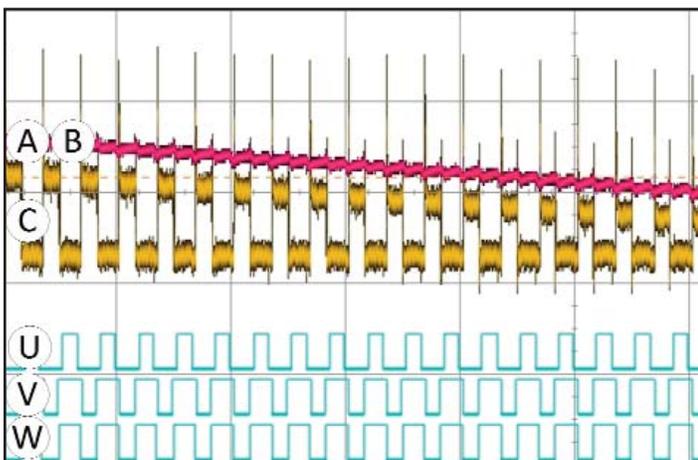


Figure 2b: A and B direct phase current, C emitter current, U, V, W upper switch actuation signals; resolution 200us/div

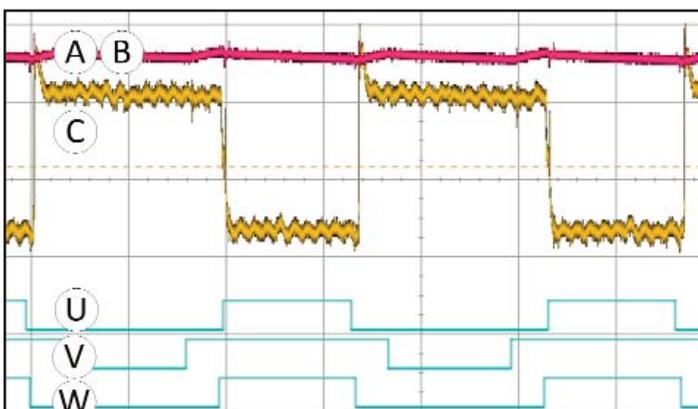


Figure 2c: A and B direct phase current, C emitter current, U, V, W upper switch actuation signals; resolution: 20us/div

### Phase current measurement using current converter

In the direct phase current measurement the microcontroller is not able to record the current directly because of the potential difference. Potential separation is possible using a current converter (B in fig. 1). This measures the current indirectly via the magnetic field, which is produced by a conductor with current flowing through it. After signal preparation an analogue signal is available to the microcontroller, which can easily be measured using an integrated analog/digital converter (ADC).

Simultaneous and equidistant measurement avoids systematic measuring errors. In order to achieve this, the sampling of the A/D conversion is synchronised to the pulse width modulation unit (PWM unit). For this purpose the XMC4500 has a large number of trigger signals, which can be used in a flexible way to start the four ADC kernels using a connection matrix.

Other analog signals such as intermediate circuit voltage, phase voltage, temperature, auxiliary voltages etc. usually also require monitoring. It is essential to avoid impairments or time delays to the current measurement.

Since an ADC cannot measure two signals simultaneously, a mechanism for prioritisation is needed that gives the current measurement priority. Characteristics such as immediate termination of a lower priority conversion, insertion of the current measurement and repeating of the cancelled conversion are essential. A well thought-out trigger and gating mechanism ensures that conversion takes place at the right time and prevents erroneous conversions.

With the XMC4000 family, priority was given to programming a complex conversion sequence consisting of several signals in advance, and allowing it to run via a time controller without any CPU involvement whatsoever. The interaction between the ADC kernels and the PWM unit is perfectly coordinated and can be flexibly designed depending on the application. (See Figure. 3 on the next page).

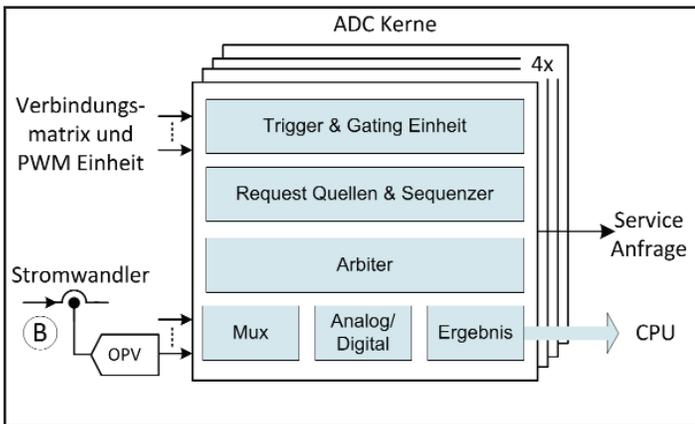


Figure 3: Block diagram of an A/D converter kernel in the XMC4500 current converter measurement

### Phase current measurement using Delta Sigma ADC

A lower-cost method is measuring using one shunt per phase. Since the phase current is continuous, an A/D converter that operates using the Delta-Sigma principle is also suitable. A Delta-Sigma ADC consists of two parts - the modulator, which records the analogue signal and converts it into a serial bit stream, and the demodulator, which converts the bit current into a readable result using a digital comb filter. An insulation section could easily be implemented between the modulator and the demodulator.

Four demodulator channels are integrated on the chip of the XMC4500 (see Fig. 4). Suitable power modules with integrated current measurement and an insulation section are available from Infineon: the MIPAQ™ family.

The digital filtering in the demodulator results in a system that is relatively slow and does not provide the latest current value; instead it provides a mean value that has been filtered via the decimation time window. The decimation factor (which is selectable by software) and the filter type determine the resolution of the measurement. If several modulators run on different clock sources, beat frequencies can occur due to clock drift. This affects the accuracy of a multi-phase measurement.

Here too the XMC4500 has a solution. When the result is read out, a time stamp is generated that provides information about the age of the measurement. The control can then achieve pseudo-synchronisation of different current sensors using software interpolation.

In order to react to overcurrents quickly, there is a separate fast filter with downstream limit monitoring for each channel.

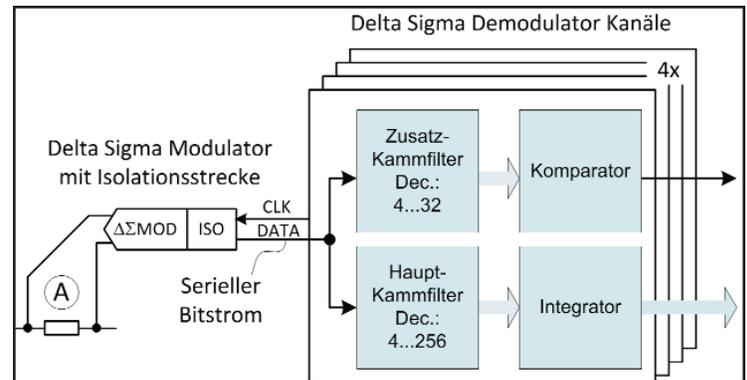


Figure 4: Block diagram of a Delta Sigma demodulator channel and isolated phase current measurement

### Emitter current measurement

As can be seen at C in fig. 2, the emitter current is a pulse-shaped and bidirectional signal. The pulse length depends on the torque and the rotor angle. Unlike the other previously-explained methods, the emitter current signal is NOT measurable at all times. Time synchronisation with the associated PWM signal is therefore required. The fact that the shunt signal has the same earth reference as the microcontroller makes signal preparation much easier. In order to minimise the power loss at the shunt and the system reaction, resistance values that are as low-impedance as possible are used, which makes signal amplification using operation amplifiers (OPV) necessary.

In order to utilise the full value range with a moderate amplification factor, load-dependent range selection can be used. In order to do this, the reference voltage range of the A/D converter from approx. 1 V to 3.6 V can be adjusted, which is made easy by the installed digital/analogue converter (DAC).

The saving in the amplification factor allows the OPV to settle faster with the same amplification bandwidth product. A fast OPV is advantageous, since it allows the extremely short sampling rate of just 70 ns (with 12-bit resolution) of the ADC in the XMC4500 to be utilized. This makes it possible to record extremely short current pulses, which occur with a small PWM duty cycle or higher switching frequencies. Another advantage lies in shifting the point in time when sampling occurs within the measuring window so that faults caused by switching on and off are masked out.

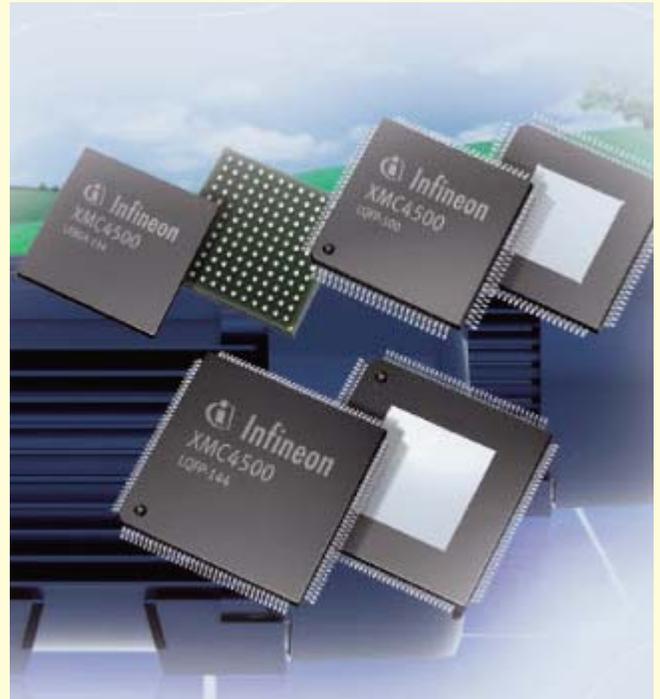
The DAC is also useful for measuring the negative currents in the emitter path by applying an offset voltage to the OPV with the second channel. Another special feature of the ADC in the XMC4500 is the result processing. Each converter unit has its own set of result registers which can be arranged to form a channel-specific buffer memory (FIFO). This makes fast multiple sampling (bursts) possible for analysing dynamic effects or forming averages. Predefined filters (FIR, IIR) can also be used on the conversion result before the CPU collects the result for further processing. Built-in limit monitoring makes it possible to react immediately to overcurrents or undercurrents. Many sensor/actuator periphery events of the XMC4500 can be wired up via a connection matrix. Fast state machines can be implemented in hardware in this way, e.g. for emergency shut-offs.

### XMC4000: Sufficient differentiation potential and security for the future

The three methods that have been explained for measuring current are the current state of technology and are used frequently in a similar or derived form. The XMC4000 family accomplishes all methods without problems. A wide-scaling frequency converter platform that makes it possible to flexibly implement application-specific optimisation can be set up using the microcontroller family from Infineon, which is based on the Cortex™ M4 Core. This provides manufacturers with sufficient differentiation potential and therefore security for the future.

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### The XMC4500 Series of Microcontrollers



The XMC4500 series is the first of the XMC4000 family to be launched on the market. Its products provide a 120 MHz CPU, up to 1 Mbyte of embedded Flash memory, 160 Kbytes of RAM and a comprehensive range of peripheral and interface functions: Among other things, the peripheral functions include four parallel and fast 12-bit AD converter modules, two 12-bit DA converters, four Delta-Sigma demodulator modules and six Capture/Compare units (CCU4 and CCU8) and two positioning interface modules and one module for eight touch buttons.

For communication purposes the XMC4500 microcontrollers support Ethernet, USB and an SD/MMC interface, and provide three CAN nodes, six serial communication channels and an external bus interface. The housing options of the XMC4500 series are LQFP-144, LQFP-100 and LFBGA-144.

For more information contact us at:  
[www.infineon.com/xmc](http://www.infineon.com/xmc)