Examination of current signals at BLDC drives

Correlation of Hall and current signals

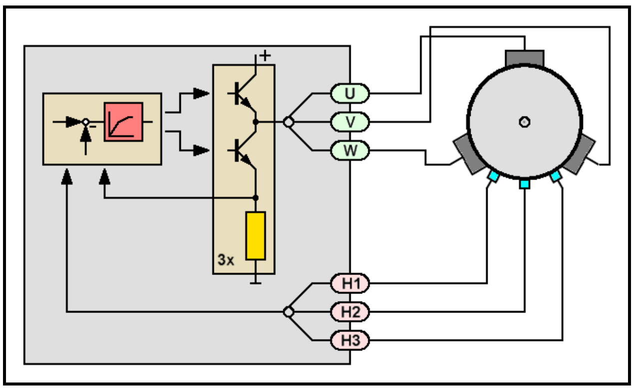
Overview:
We have designed a device to simplify the initial operational phase of BLDC drives, with the combined examination of Hall signals and phase current signals. So it is very simple to verify the correct wiring scheme and to investigate the current controller by analysing a single current signal.

The advantages of BLDC drives (brushless direct current) are good reasons to use them in highly dynamic actuation systems. But the step from the brush or stepper motor to the Hall controlled brushless servo motor is connected with an significant increase in complexity, visible last, but not least in the installation. While a brush motor has just two wires, a brushless motor has (at least) three motor phase cables, three Hall sensor signal wires and 2 supply cables for the Hall sensors, making a sum of 8 cables.

The motor drive electronic consists mainly of a regulator or controller (for current, speed, position) and a power stage (three times identical). The controller detects the Hall signals and the phase current signals (shown as shunt signals). Then the power stage activates the three motor phases.

It is a popular strategy to keep one motor connection without power. This block commutation strategy is the simplest method to operate a BLDC motor. The active or “equivalent” motor current is then running through the one or the other motor phase, (depending on the rotor position detected by the Hall sensors). So it is not enough to measure just a single motor phase to determine the state of the motor.

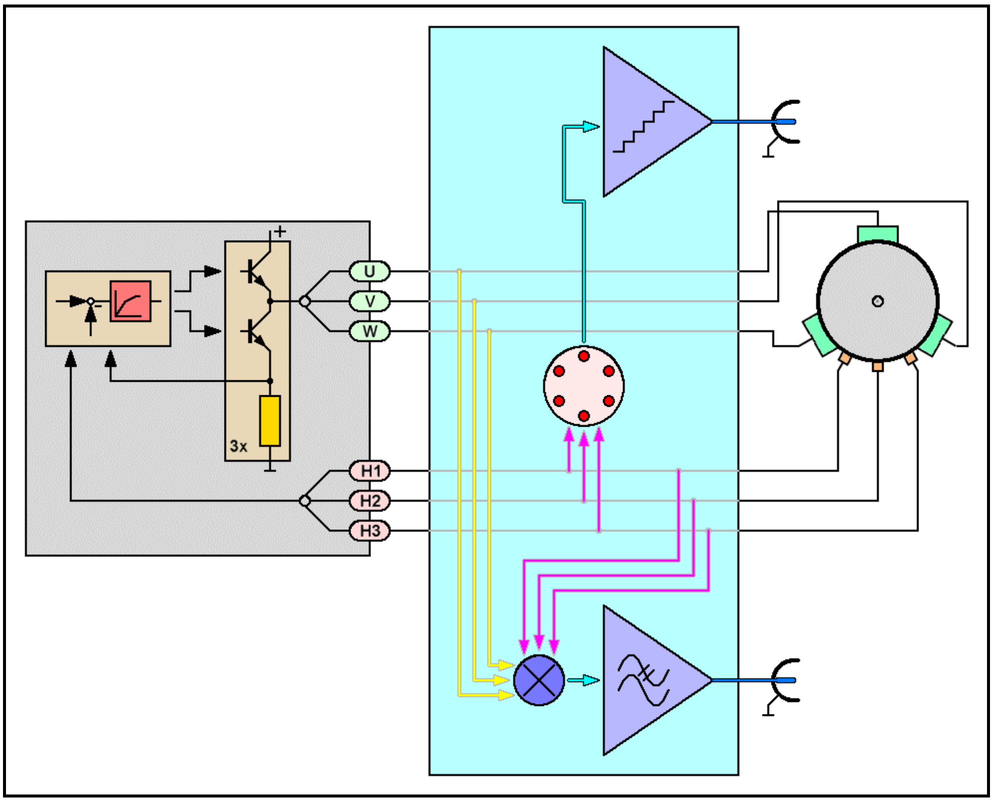
But also the complexity of the signals is increased: while a brush motor has a just single motor current, a brushless motor has three currents, more or less permanently. The three Hall signals also add to the complexity, as they control the commutation between the three motor phases. While it was enough to observe a single current signal with a brush motor, with a brushless motor it is necessary to observe six signals.



It is very convenient during the initial operational phase when the motor drive generates a synthetic current signal, based on its sensors, rather than analysing all three motor phases by hand. But this is a rare feature.

The alternative is to use a current probe to measure the global current (neglecting the details of the current control or the power stage) or three sensors to measure the phase current. Both ways are not completely sufficient.

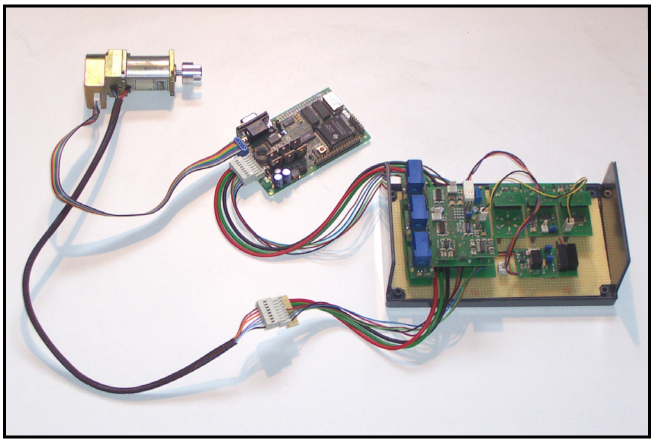
For this important initial operational phase we have developed a device which is also suited for more thorough investigations (as for model identification). The device analyses both the motor phase currents and the Hall sensor signals and generates a single analog signal, representing the “equivalent” current.

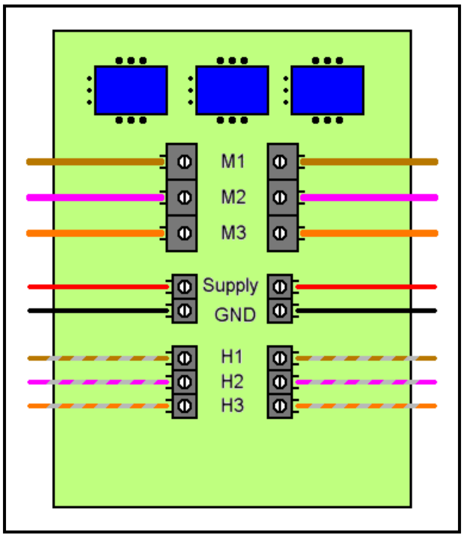


Furthermore it generates a rotor position signal to check the correct commutation. For this reason the six steps of the block commutation strategy are converted in an optical display (arranged like a clock) and an analog step signal, generating two very intuitive tools.

The device is simply attached to the motor wiring (e.g. by an adapter cable).

The photograph shows how the device is located between power stage and motor. Neither the operation of the power stage nor of the motor are compromised.



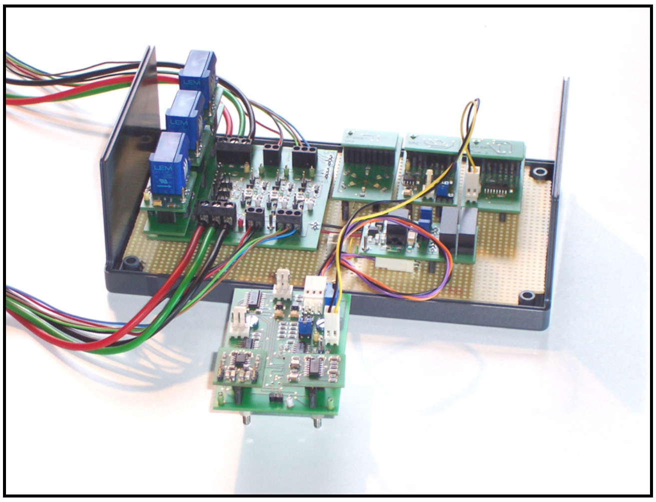


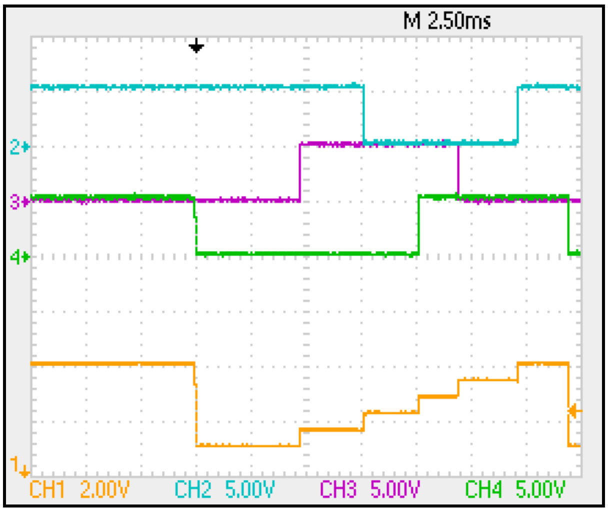
The Hall sensor supply is just fed through the device, but is not used to power the device. The wiring scheme is simpler, when cables coming from the left are also connected at the right side. So it is just a matter of comparing colours for a correct installation.

The device is powered by battery.

The layout of the device is modular. So it is easy adaptable to different current levels or Hall sensor arrangements. The version on the photographs is appropriate for phase currents of about 10 A.

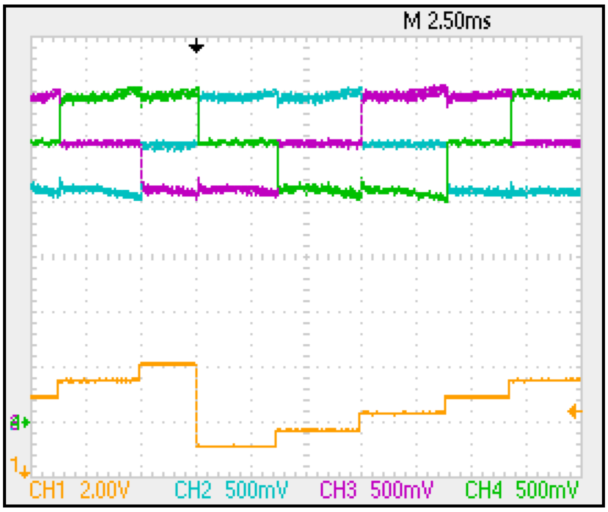
The signal processing board has two sockets for different filters. The board is placed directly above the connecting clamps (detached for the photograph).





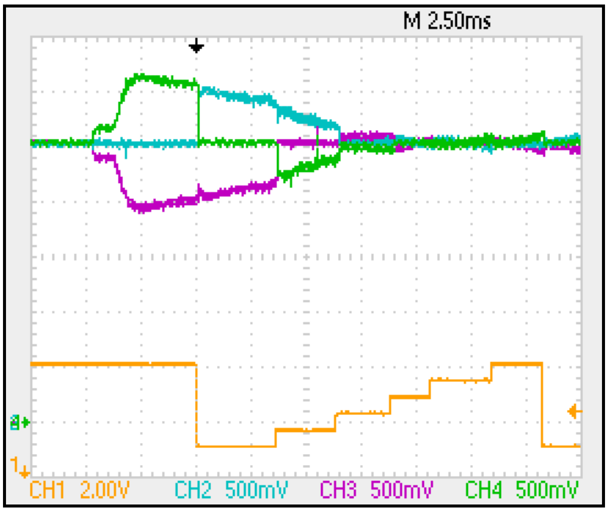
The three signals on top are the Hall sensor signals of a motor starting from halt. The three digital signals were combined inside the device to a compact analog signal, shown as the lower trace (1). The six steps of the block commutation make a triangle step signal, indication the direction of rotation.

The condensation of three signals to a single analog signal saves measurement channels and creates a better insight..

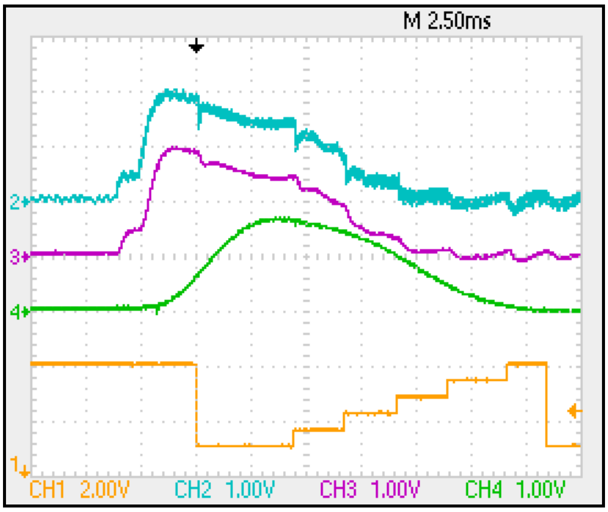


When the motor is loaded with an uniform torque, the three motor phase currents are a shown. There is always a signal at zero.

Comparing the step signal of the block commutation and the current signal makes clear, that there is always a different current combination at any different commutation step.

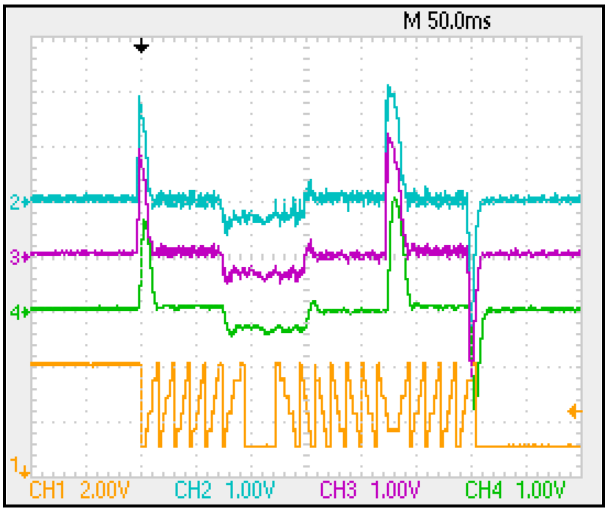


The case is similar when starting the motor. There is a change in the current combination at any different commutation step.



The upper trace (**2**) is now the equivalent motor current. It is useful to pass the signal through a low-pass filter. So the remaining PWM is reduced, otherwise spoiling the overview. Depending on the focus different filter characteristics are appropriate.

The two lower traces show the current signal after a low-pass filter:
(**3**) with a Bessel filter 1 kHz, 2. order,
(**4**) with a Bessel filter 100 Hz, 4. order.



The flexibility in filtering is the reason for the use of exchangeable filter sockets. It is also convenient to switch between two different filter characteristics and to see the effect at once on the scope. This simplifies the examination of the current signals.

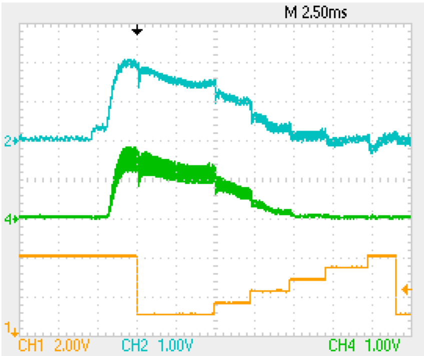
The screen shot over a longer time shows the full motion cycle (forwards and backwards), as indicated by the rising and then fallings steps.

At this time scale the slower filter seems more ideal, creating smoother signals.

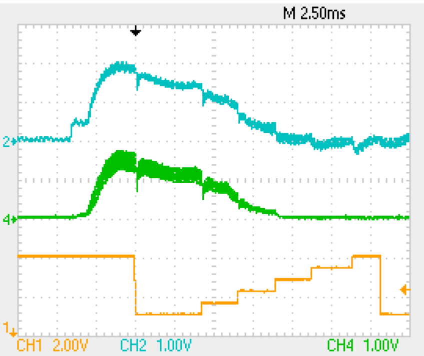
The condensation of the Hall signals and the three current signals to a single equivalent current enables a very clear view on the effects of control parameters on BLDC motors as it was with brush motors.

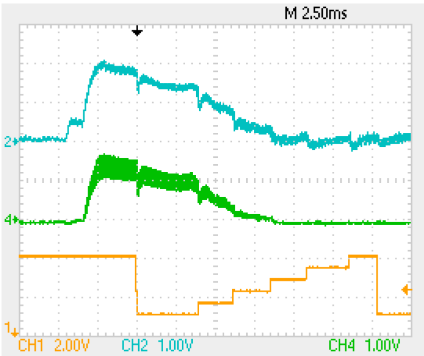
The following 5 pictures show the effects by changing the parameters of the current controller (PI controller), starting from the nominal values and changing in both directions. The vertical series varies the proportional factor, while the horizontal series varies the integral factor.

$K_p = K_{p,0} * 1.5$



$K_i = K_{i,0} / 1.5$





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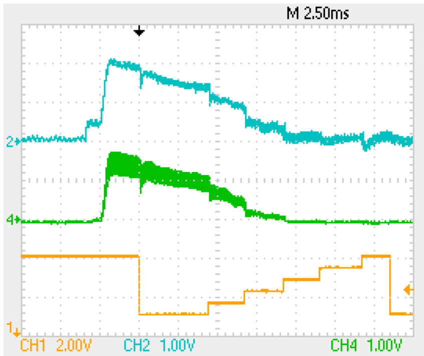
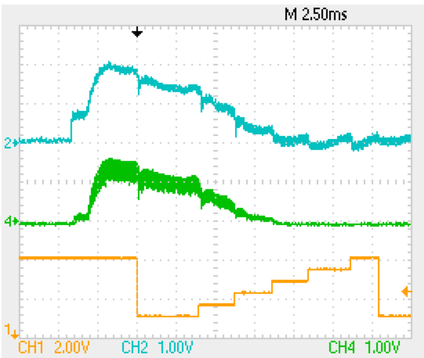


$K_p = K_{p,0} / 1.5$



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