

Motor PWM Coupling on 100m Hybrid Cables

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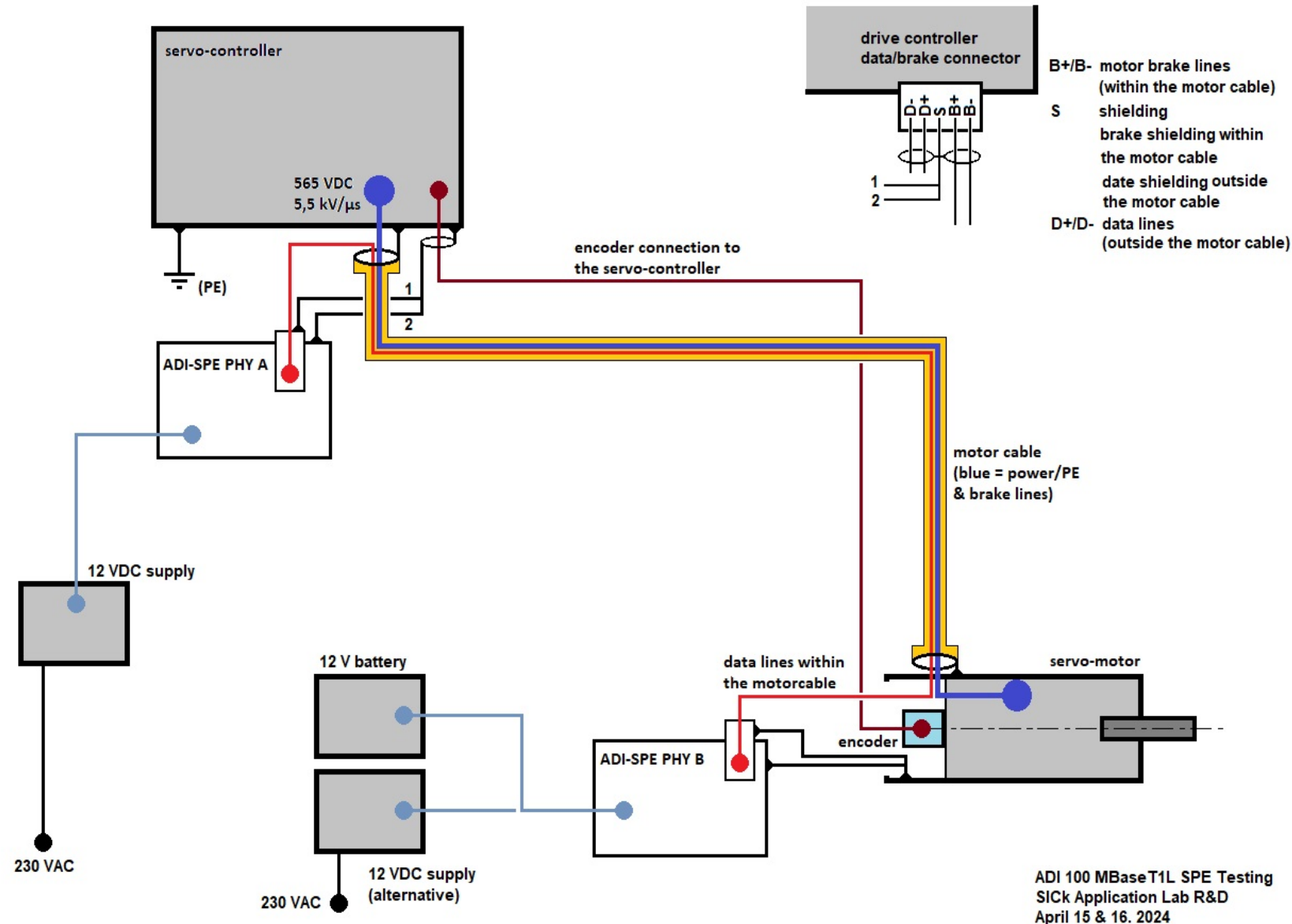
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Motor PWM Coupling on 100m Hybrid Cables

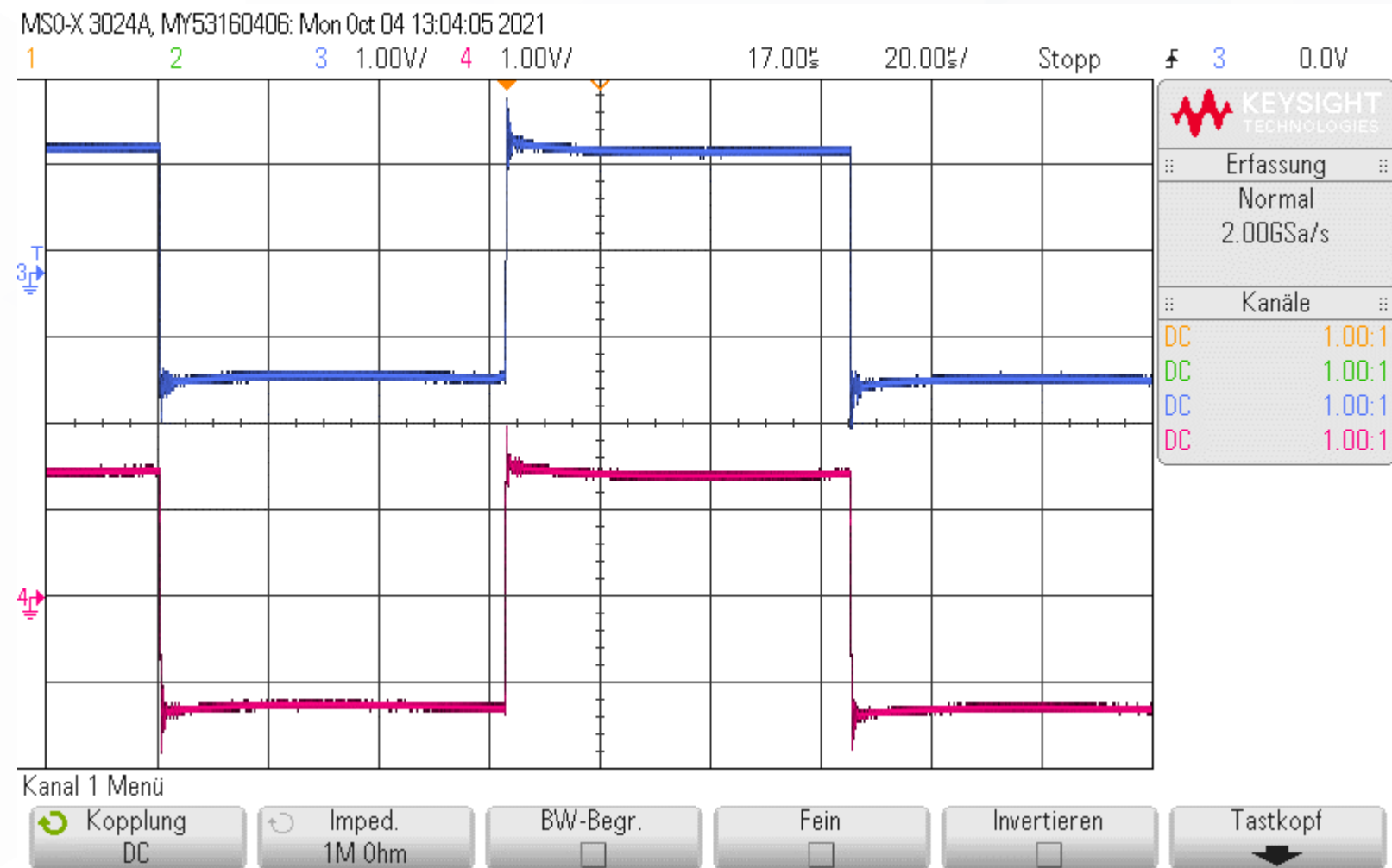
- ▶ Measurement setup
 - Controller / Drive and Motor
 - Data Acquisition (DAQ)
 - Motor Hybrid Cables
- ▶ 5m Standard Hybrid Cable
 - Setup validation
- ▶ 100m Standard Hybrid Cable
 - PAM3 signal
 - PWM coupling
- ▶ 100m Advanced Hybrid Cable
 - PAM3 signal
 - PWM coupling
- ▶ Discussion
 - Margin of PAM3 vs. PWM coupling

Measurement Setup

Measurement Setup



Servo Controller / Drive PWM Signal



- ▶ Shown 2 out of 3 PWM signals
- ▶ Captured with high voltage 200:1 oscilloscope probes
- ▶ 16kHz / 62.5us period 3-phase PWM
- ▶ Amplitude approx. 565V
- ▶ Slew rate approx. 5.5kV/us
- ▶ Rise time approx. 100ns
- ▶ Motor powered, in holding position, not turning
 - The phases switch nearly at the same time, a few ns in-between only.

Hybrid cable

- ▶ Cable for connecting of motor setup incl. encoder and positioner with motor drive / controller
- ▶ Cable includes power & brake lines together with communication lines within one cable

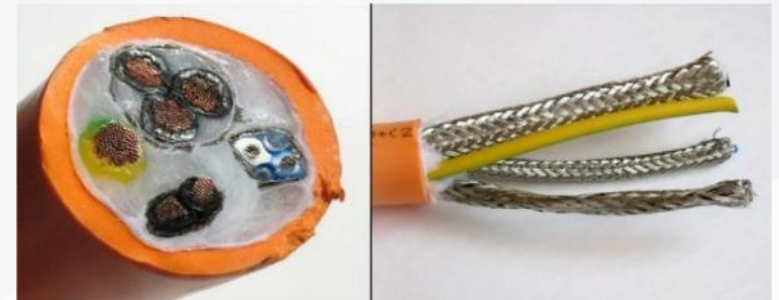
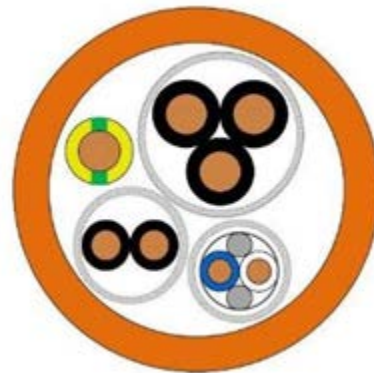
“Standard” Hybrid Cable

- ▶ Length: 5 m & 100 m
- ▶ Configuration:
[4G1,5+(2x0,75)/C+(2xAWG22)/C]C



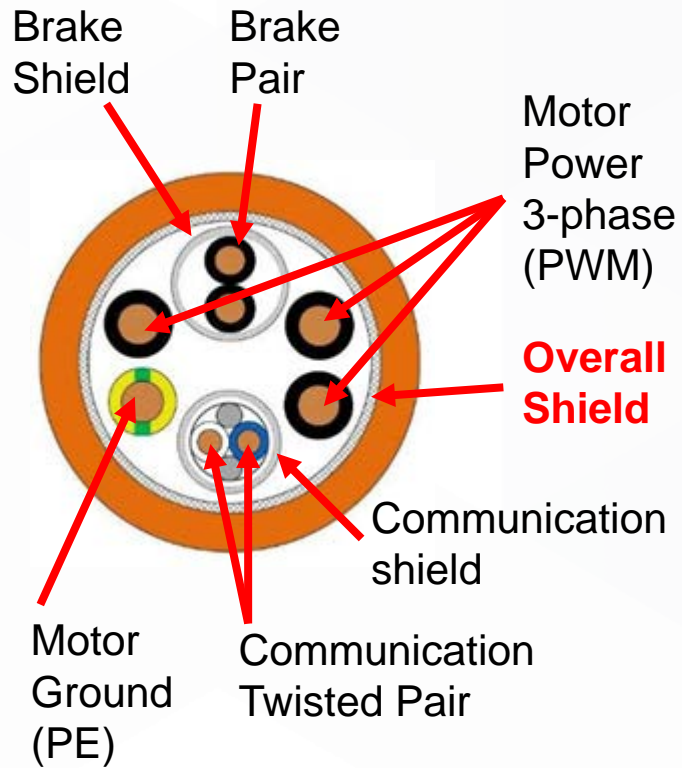
“Advanced” Hybrid Cable

- ▶ Length: 100 m
- ▶ Configuration:
[4G1,5+(2x0,75)H2+(2xAWG22)H2H]H2

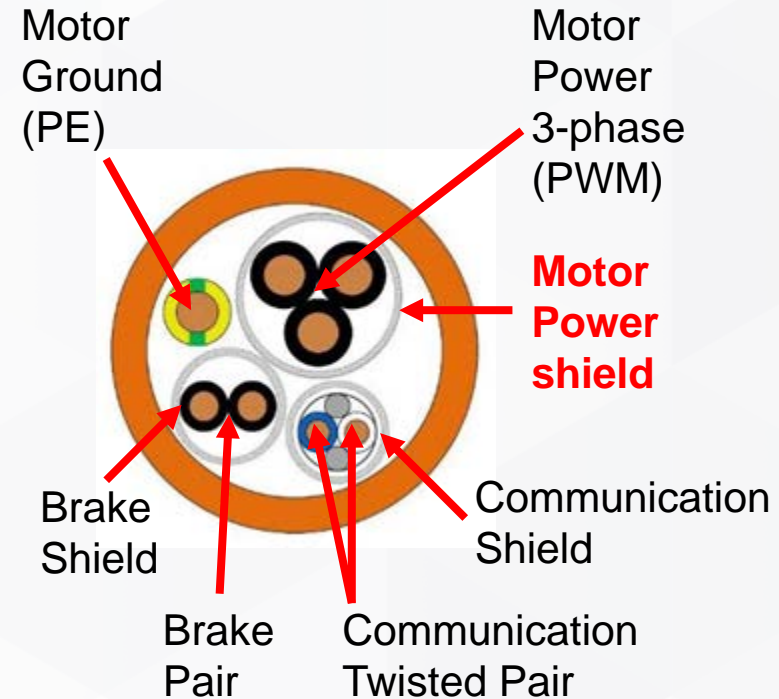


Hybrid Cables

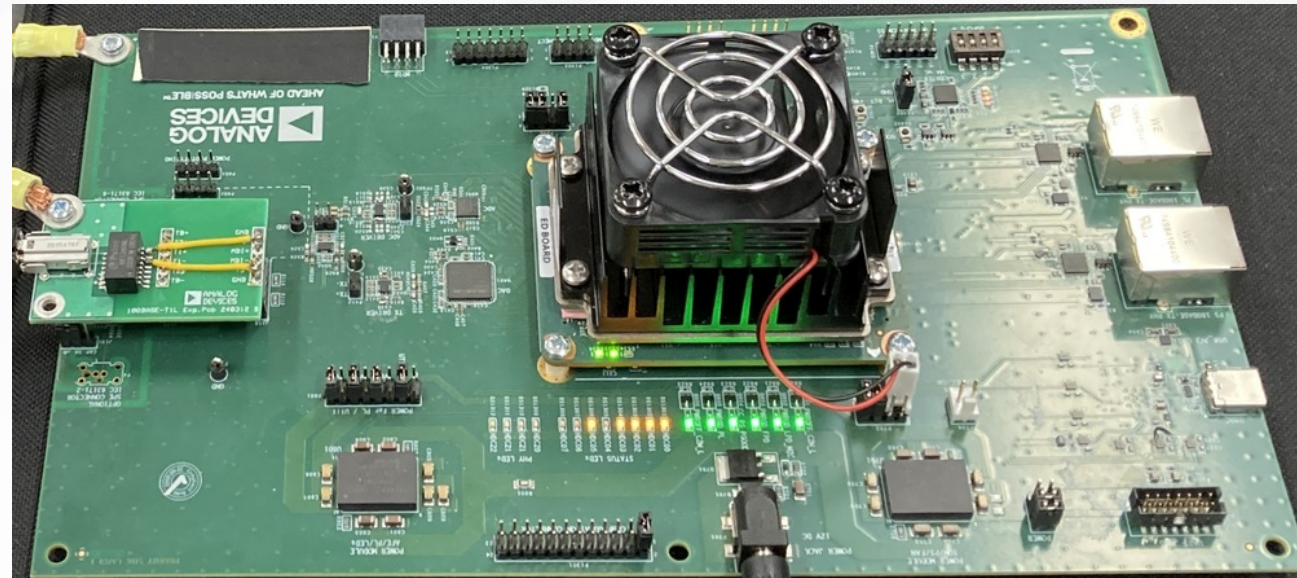
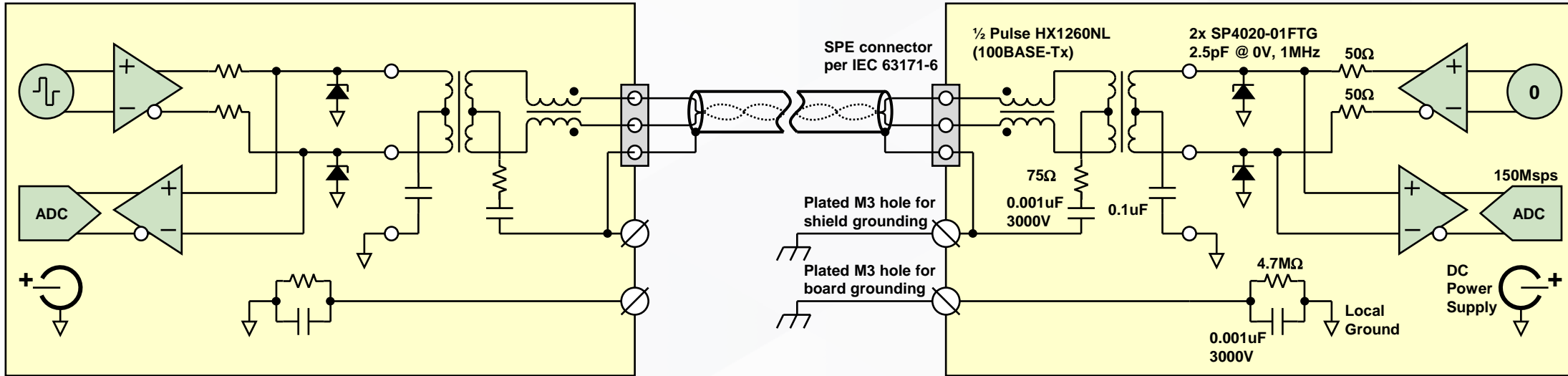
“Standard” Hybrid Cable



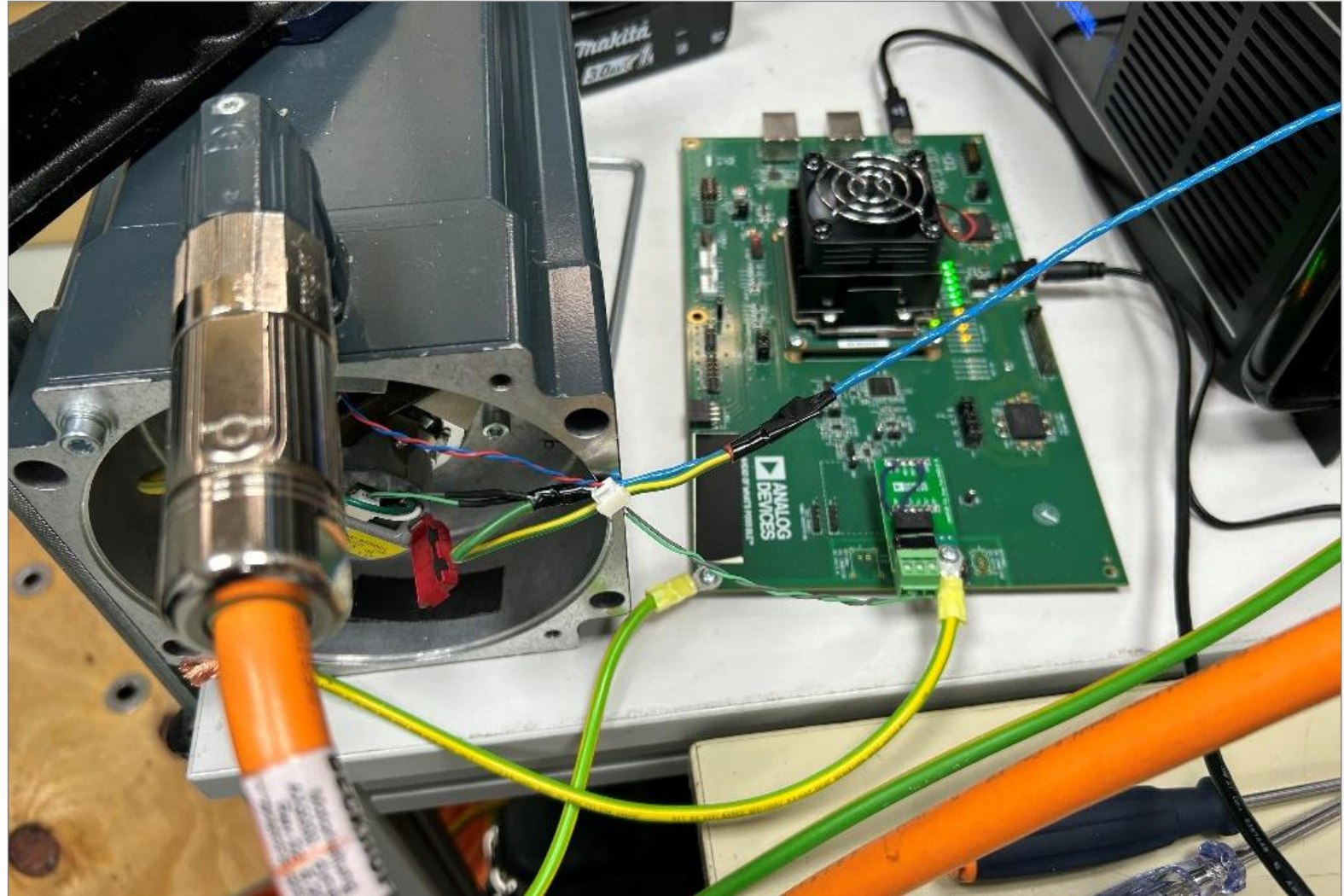
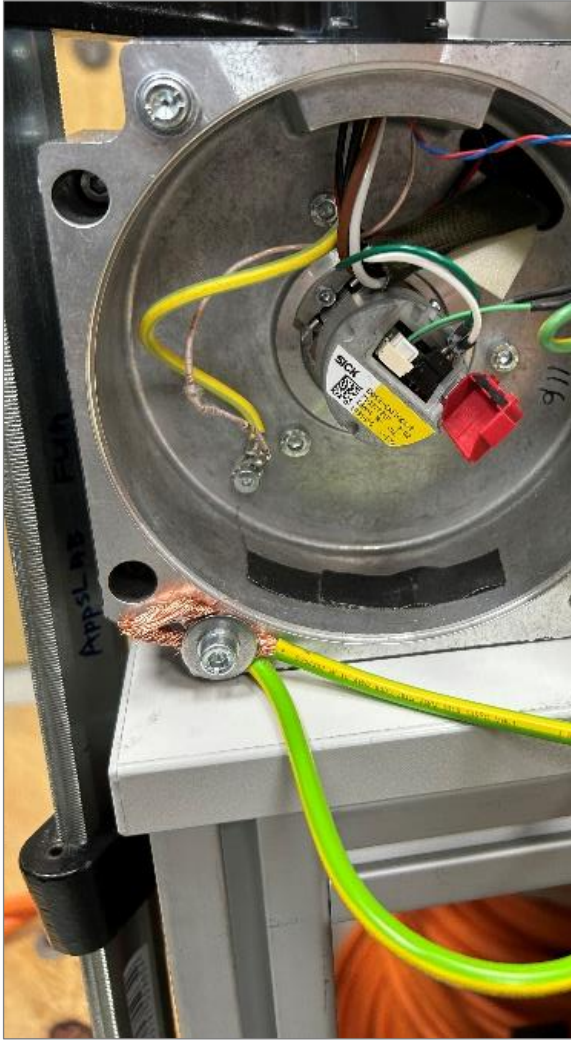
“Advanced” Hybrid Cable



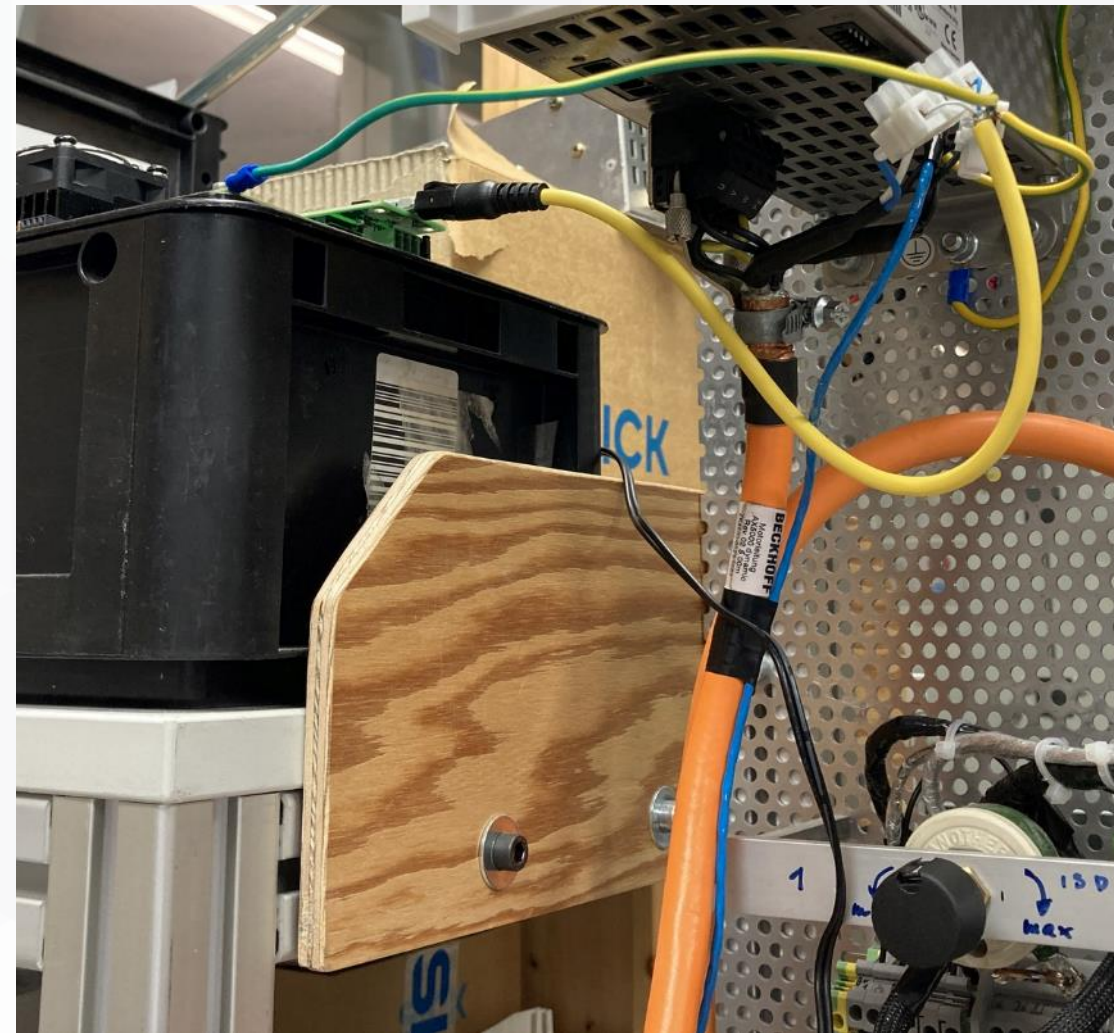
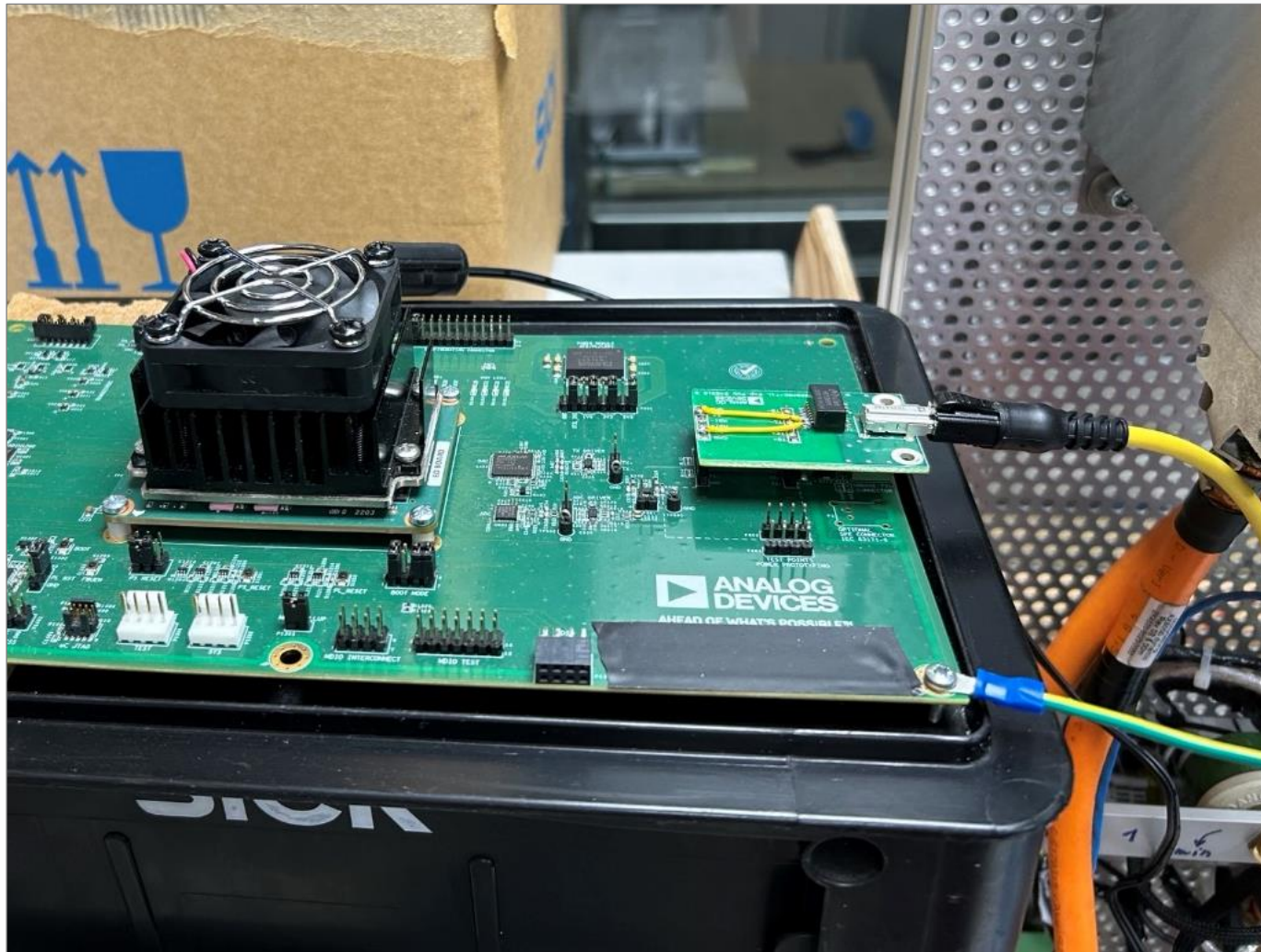
Data Acquisition (DAQ) used for Measurements



Measurement Setup - Motor Side



Measurement Setup – Controller / Drive Side

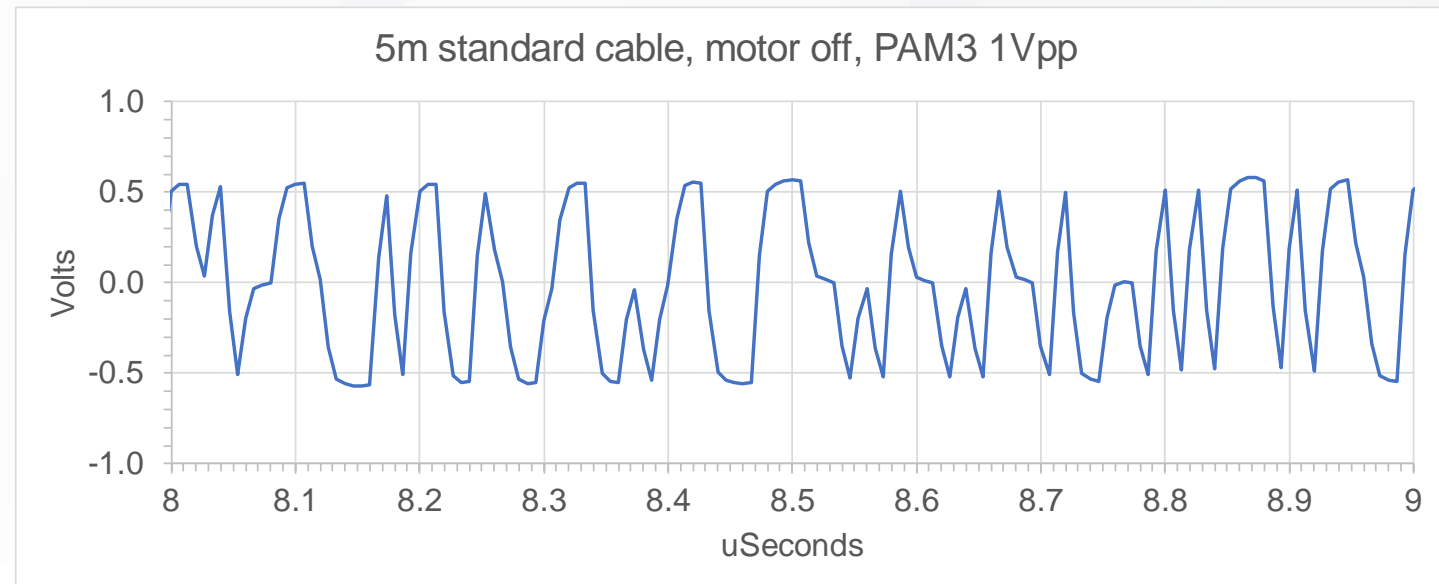
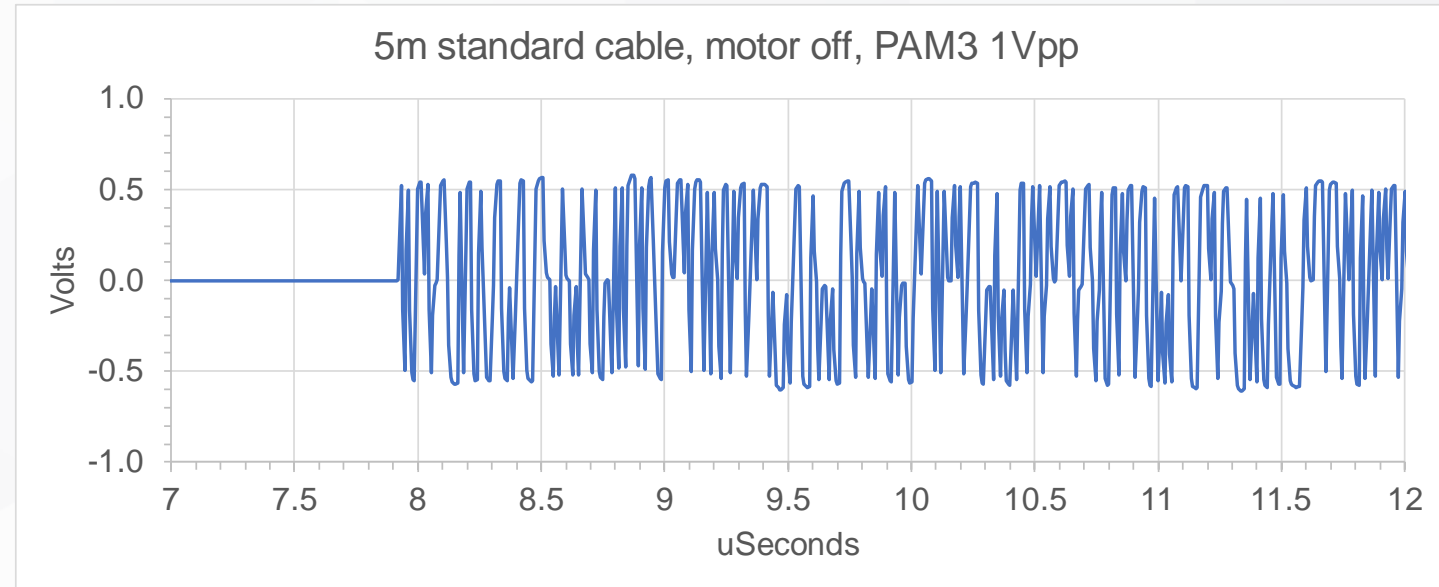


5m Standard Hybrid Cable

Measurements for Setup Validation and Reference

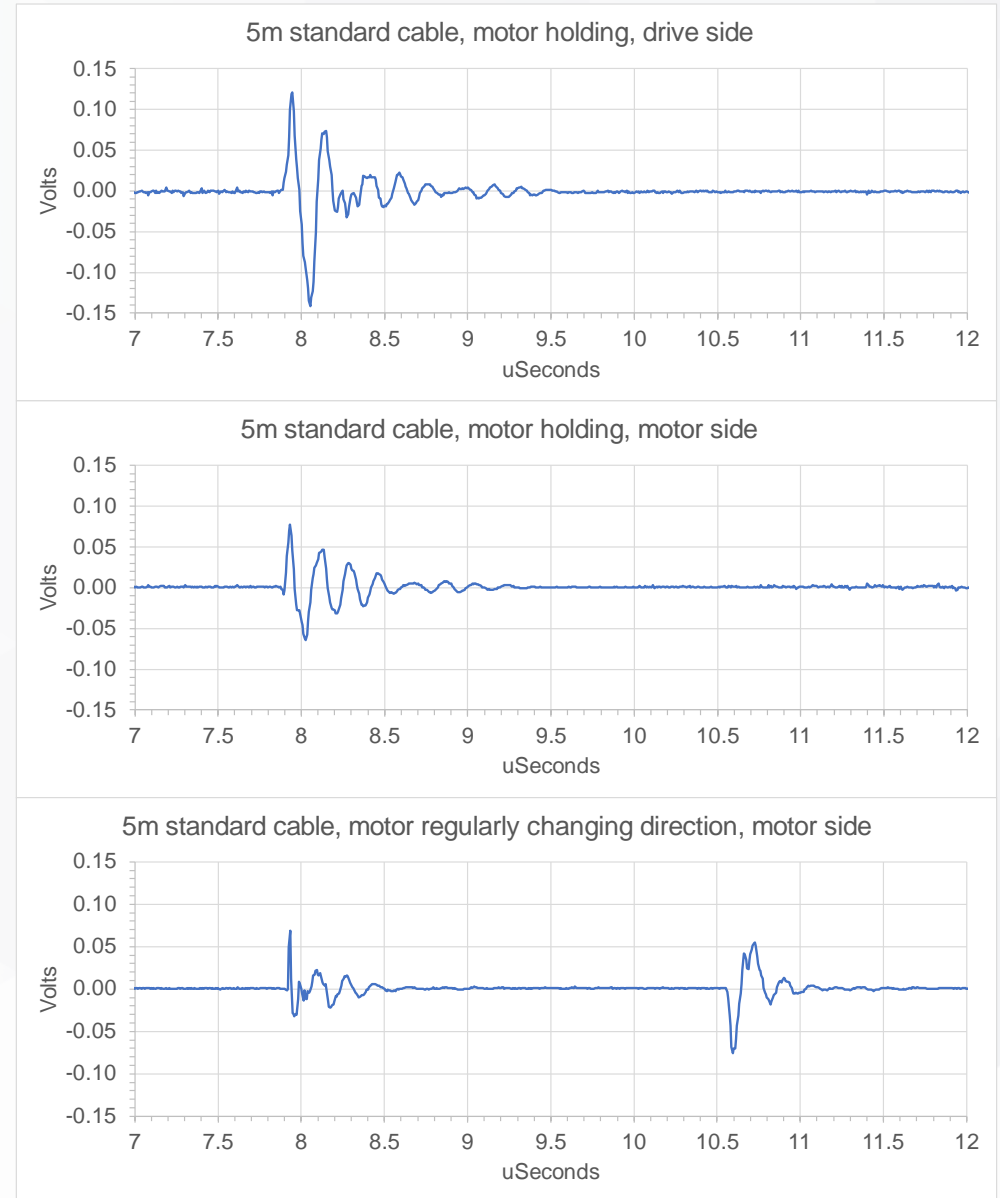
5m (short) standard hybrid cable - PAM3 1Vpp Signal

- ▶ The Data Acquisition (DAQ) on one side of the cable transmitting a PAM3 1Vpp signal
- ▶ The DAQ on the other side of the cable capturing the signal
- ▶ No visible attenuation of the signal on 5m hybrid cable



5m cable – PWM Coupled to Communication Pair

- ▶ The Drive outputs 3-phase PWM signal
- ▶ The Drive keeps the Motor in “hold” position
 - Motor supplied by PWM signal, but not turning
 - Only one narrow disturbance in 62.5us period
 - Identified as the worst-case condition for disturbance amplitude
- ▶ DAQ on both sides capturing the signal coupled from the PWM power lines to the communication differential pair
- ▶ The bottom capture is the same setup
- ▶ The Motor is regularly changing direction
 - Motor actively driven here
 - More than one disturbance pulse in 62.5us PWM period
- ▶ Compare / Refer to presentation “Brychta_3dg_01_0524”

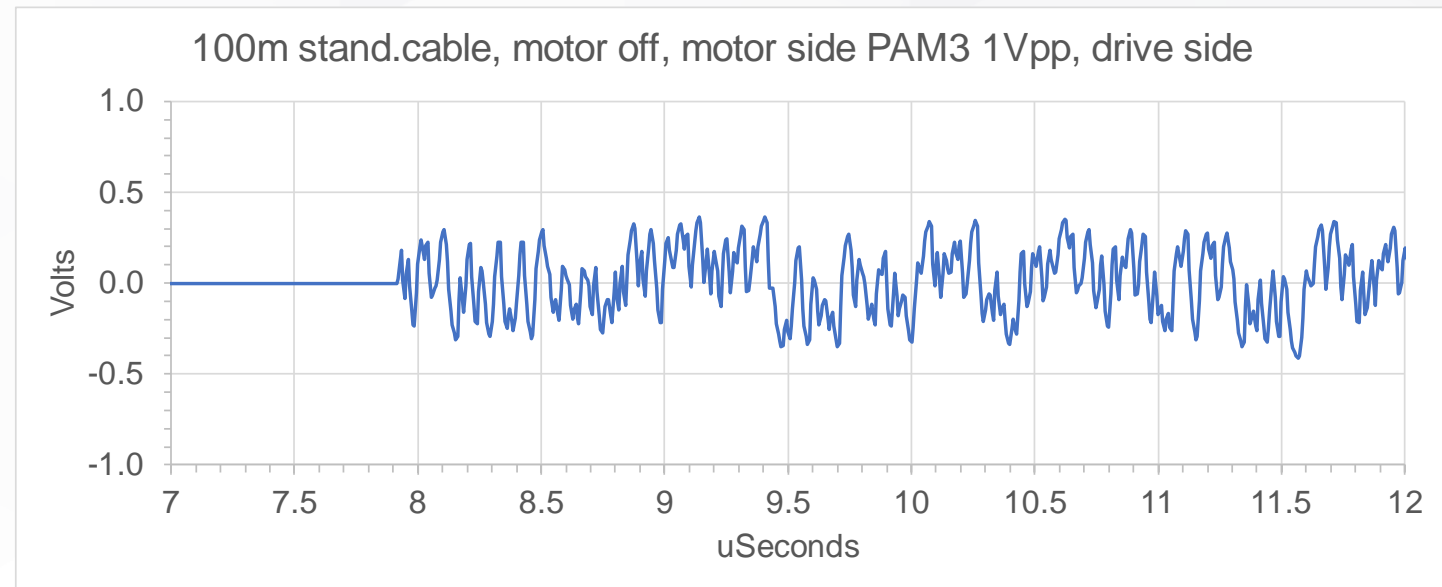
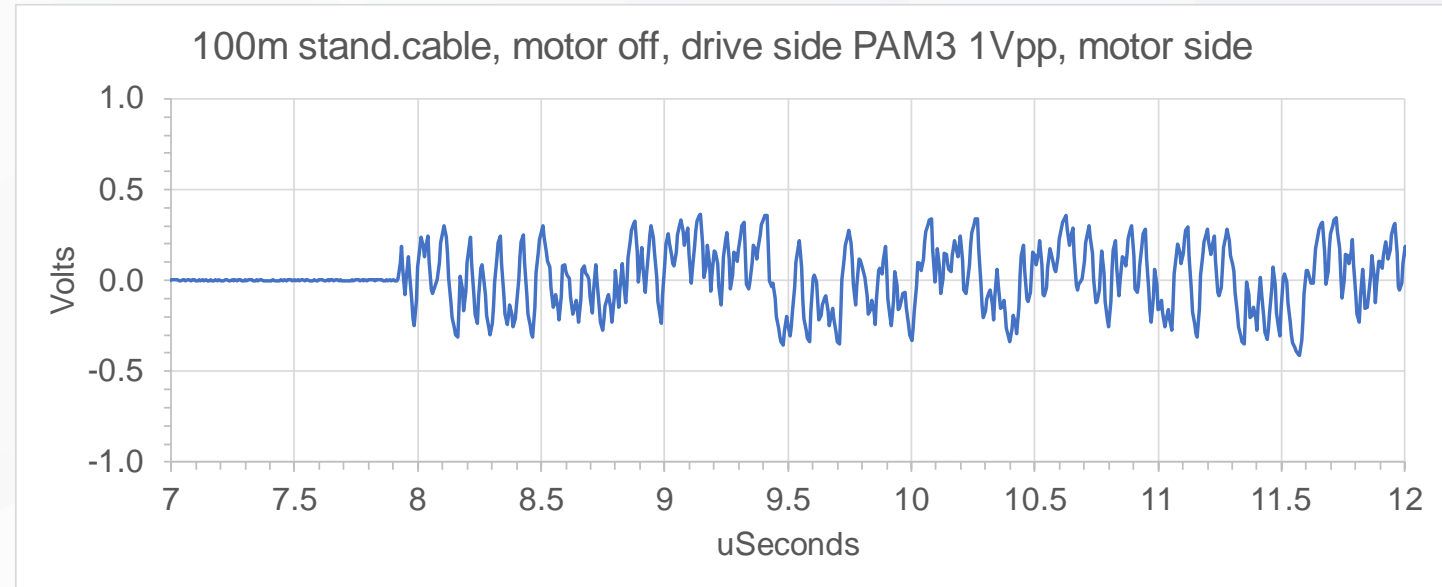


100m Standard Hybrid Cable

Measurements

100m standard cable - PAM3 1Vpp Signal

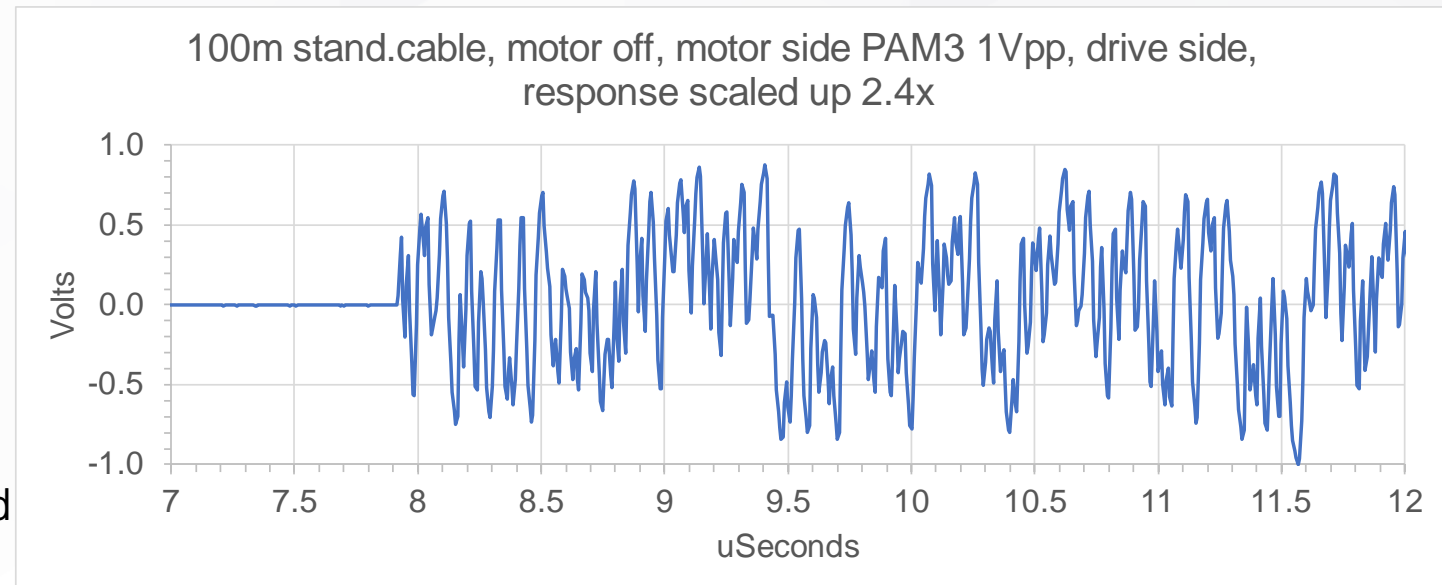
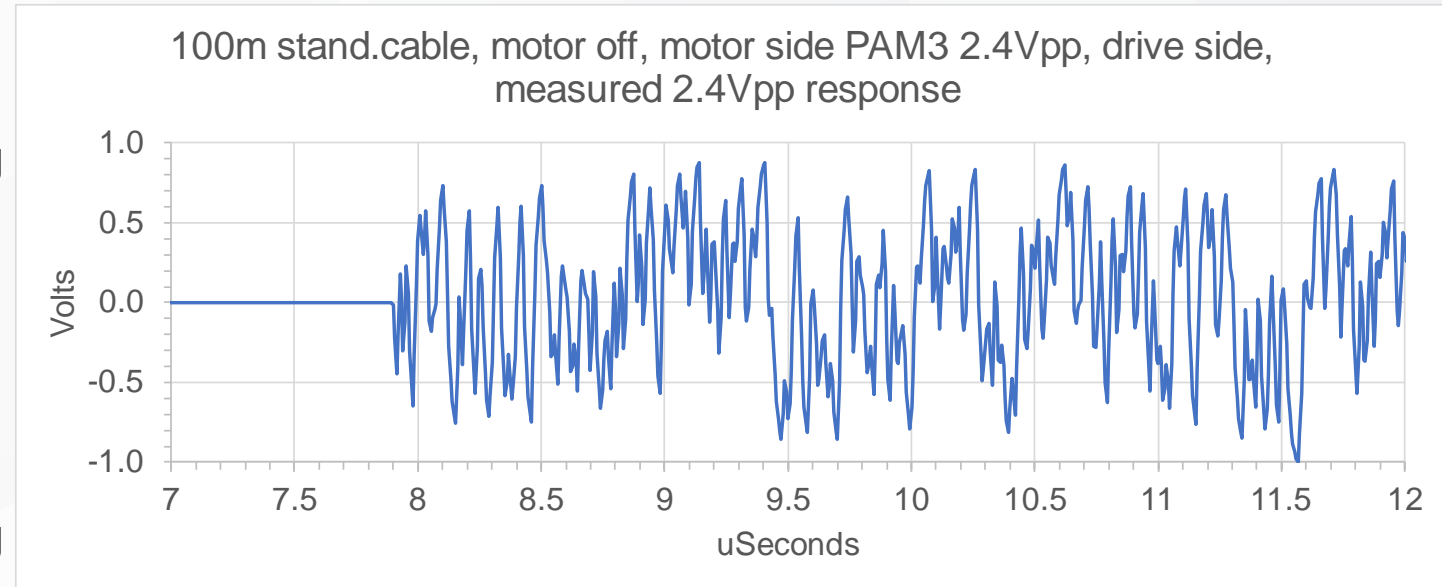
- ▶ The Data Acquisition (DAQ) on one side of the cable transmitting PAM3 1Vpp signal
- ▶ The DAQ on the other side of cable capturing the signal
- ▶ Signal attenuated and shape changed
 - Cable frequency dependant insertion loss
 - Signal captured directly on ADC output
 - PHYs will implement digital equalisation
 - To re-shape the signal back...



PAM3 Signal – Changed Amplitude – Linear Scaling

- ▶ The Data Acquisition (DAQ) on one side of the cable transmitting PAM3 2.4Vpp signal
- ▶ The DAQ on the other side of cable capturing the signal

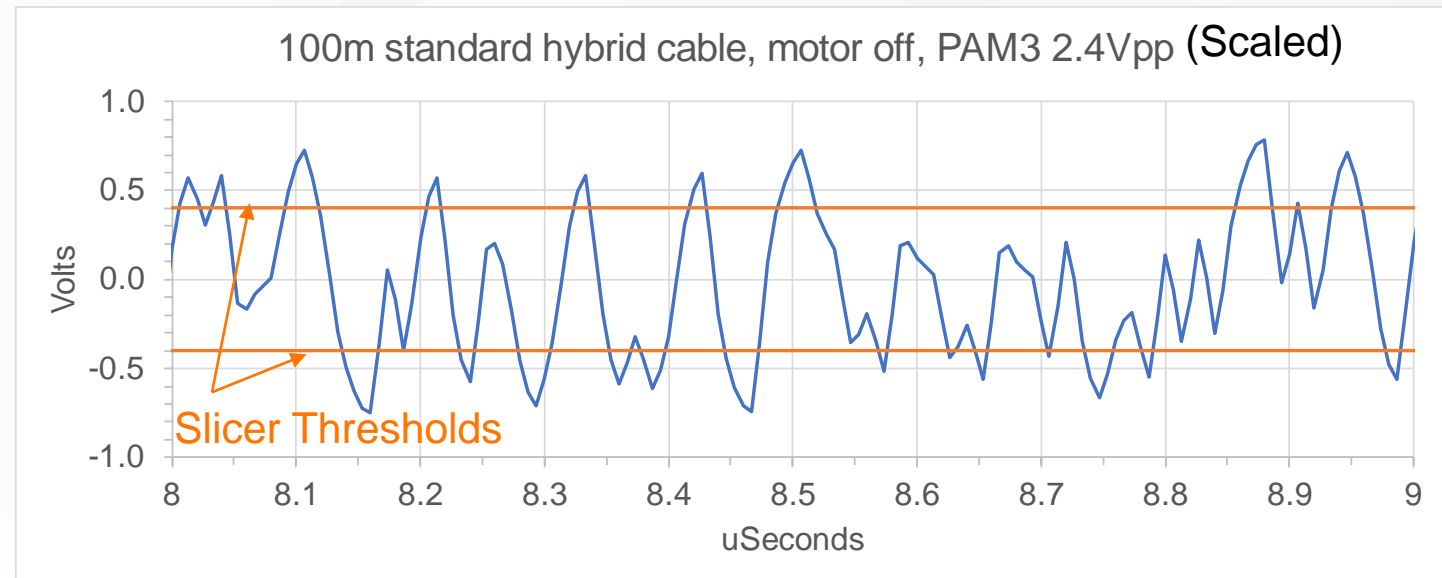
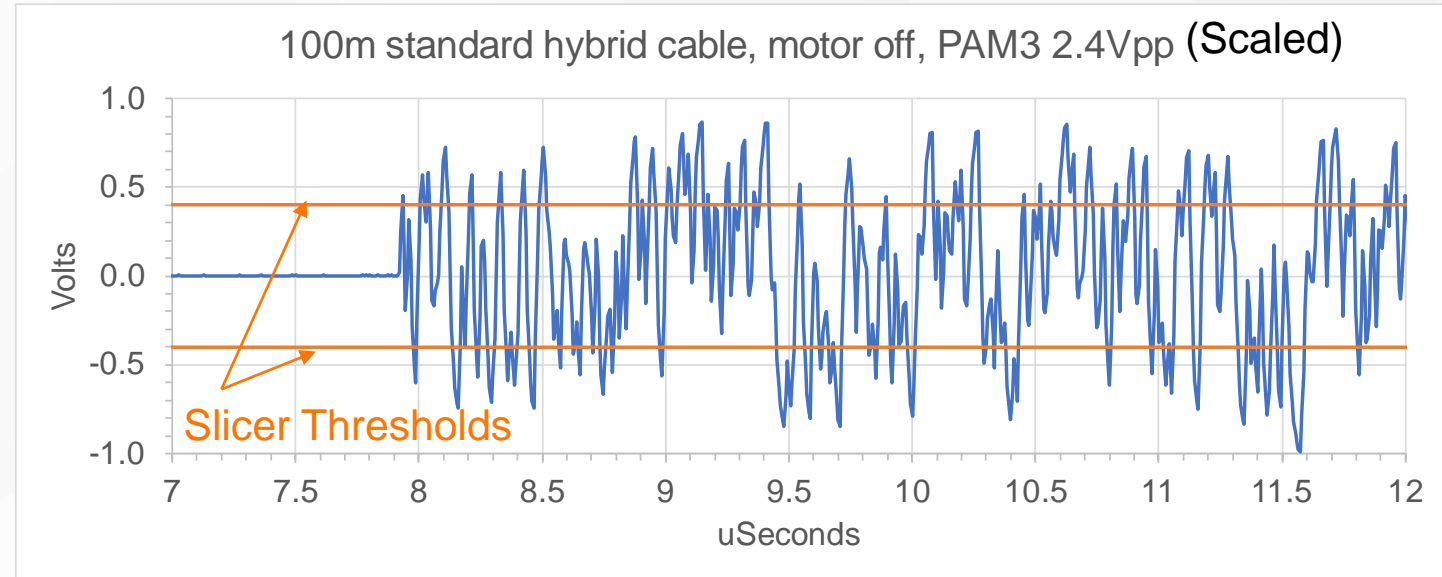
- ▶ The Data Acquisition (DAQ) on one side of the cable transmitting PAM3 1Vpp signal
- ▶ The DAQ on the other side of cable capturing the signal
- ▶ The captured signal subsequently scaled
 - In spreadsheet
 - Multiplied 2.4x
- ▶ Comparison shows almost no difference
- ▶ We can mathematically scale signal for signal to noise (disturbance) ratio estimations
 - Assuming we can implement a higher transmit amplitude
 - Assuming receiver noise is negligible compared to the system / disturbance noise



PAM3 Signal – Estimation of Slicer Threshold

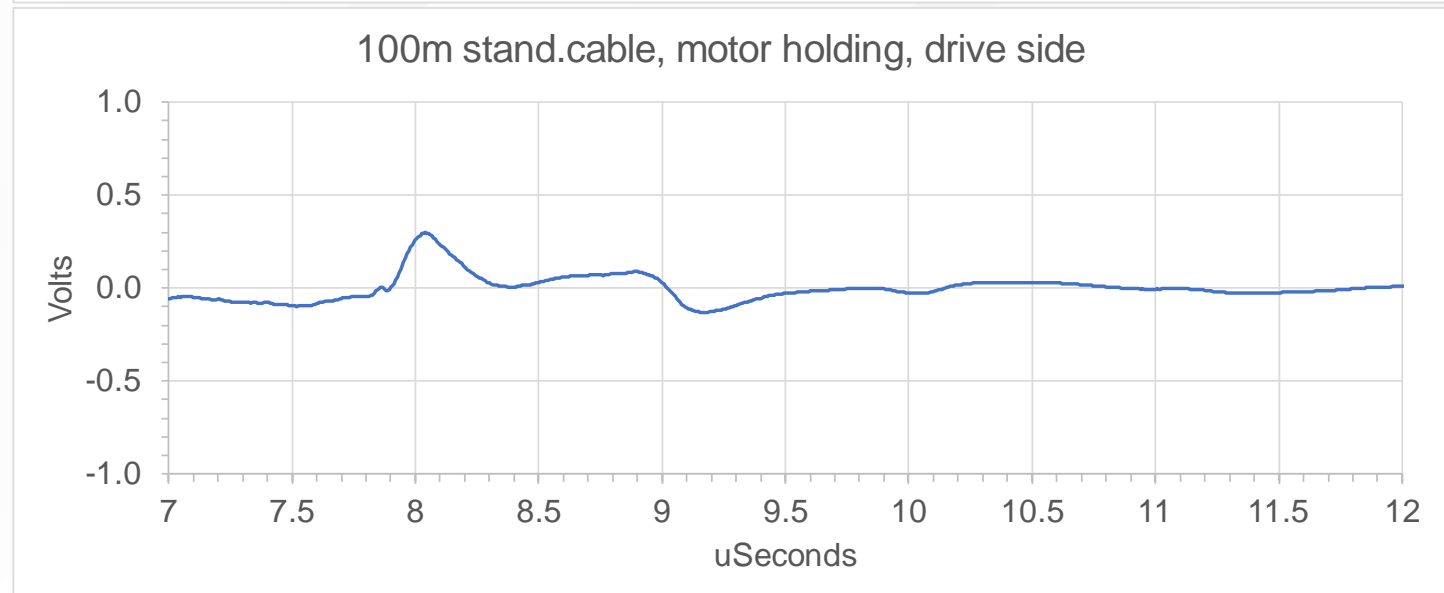
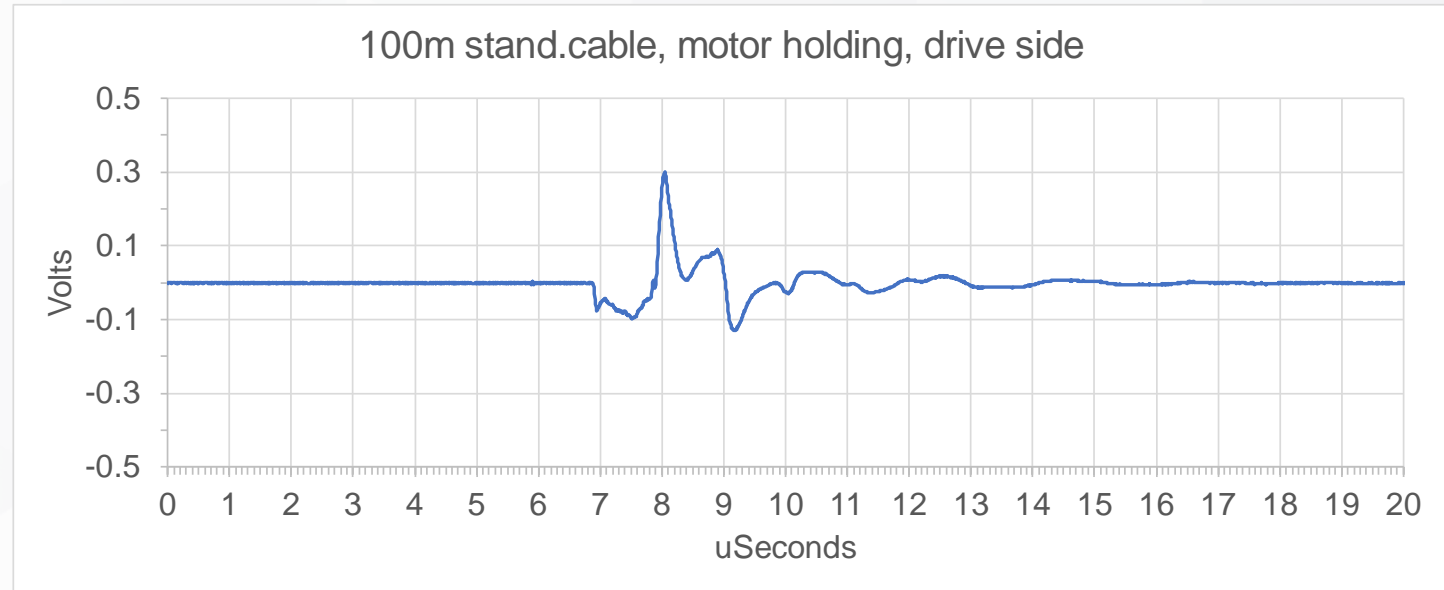
- ▶ Signal attenuated and shape changed
 - Cable frequency dependant insertion loss
 - Signal captured directly on ADC output
 - PHYs will implement digital equalisation
 - To re-shape the signal back...

- ▶ Estimating / setting slicer threshold as approximately half of the received signal peak amplitude
 - Received signal approx. $\pm 0.8V$
 - Setting / showing slicer thresholds at $\pm 0.4V$

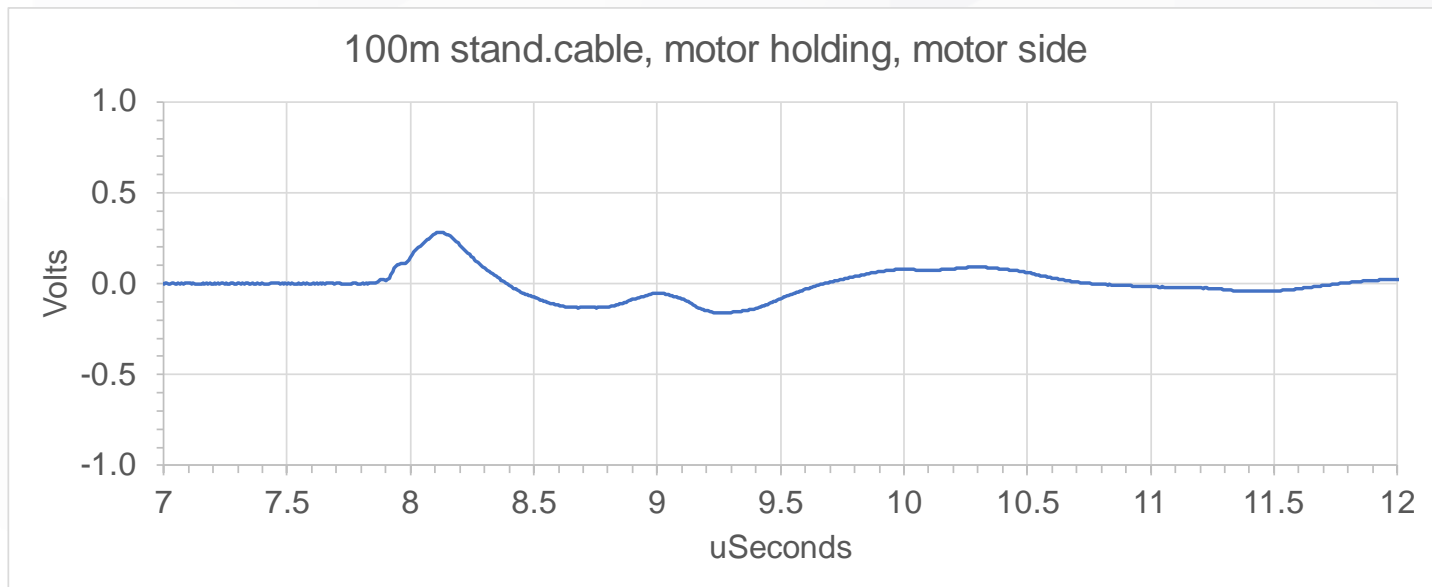
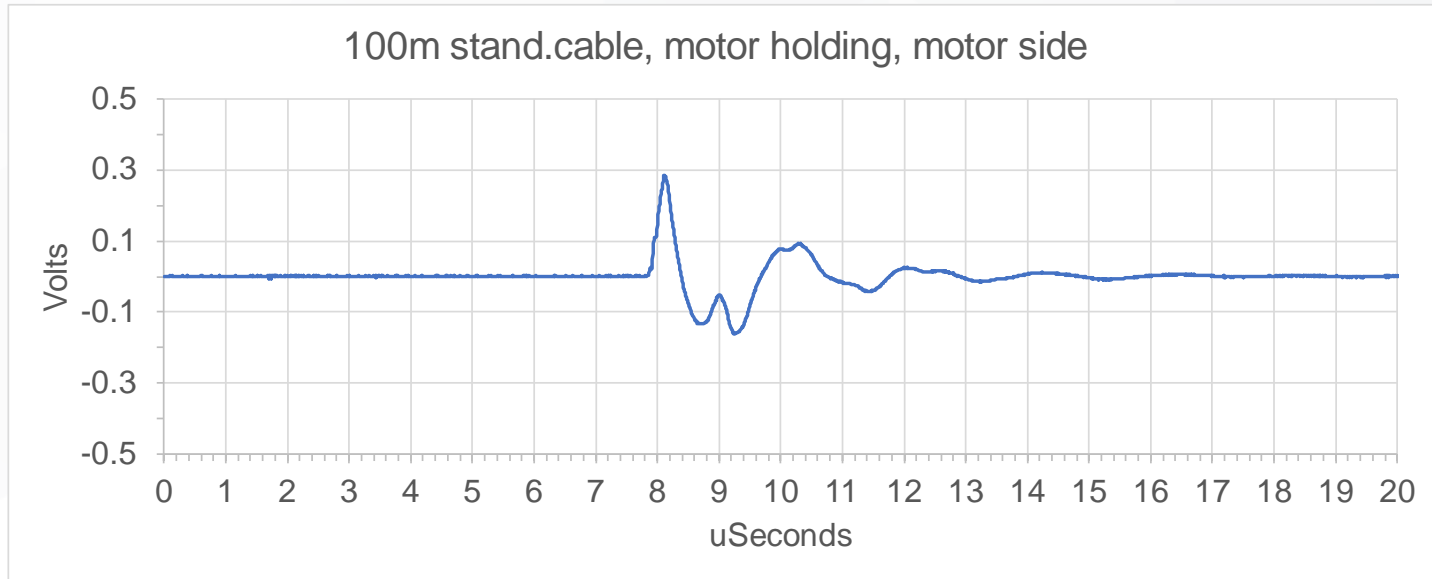


Signal Coupled to Communication Pair (Drive Side)

- ▶ The Drive outputs 3-phase PWM signal
- ▶ The Drive keeps the Motor in “hold” position
 - Motor supplied by PWM signal, but not turning
 - Identified as the worst-case condition for disturbance amplitude
- ▶ The DAQ on DRIVE side capturing the signal coupled from the PWM power lines to the communication differential pair

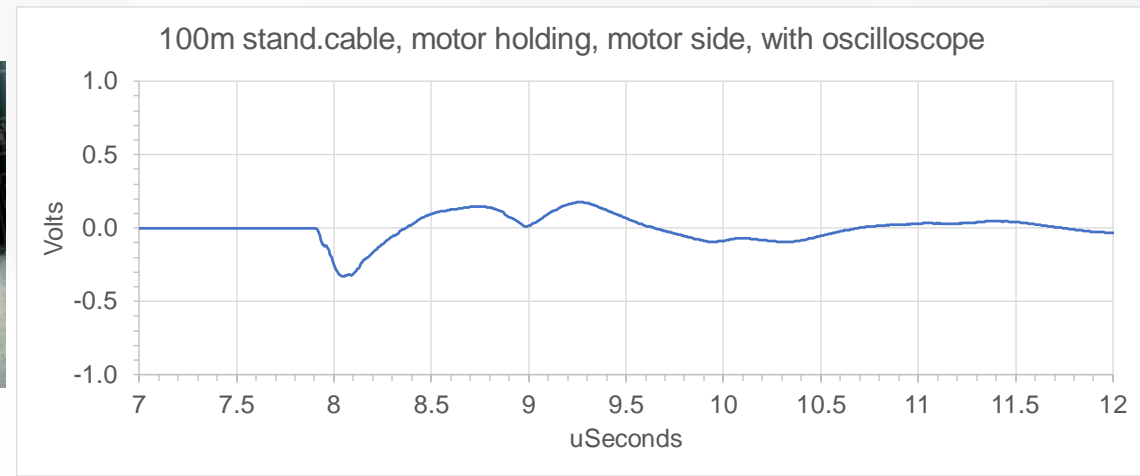
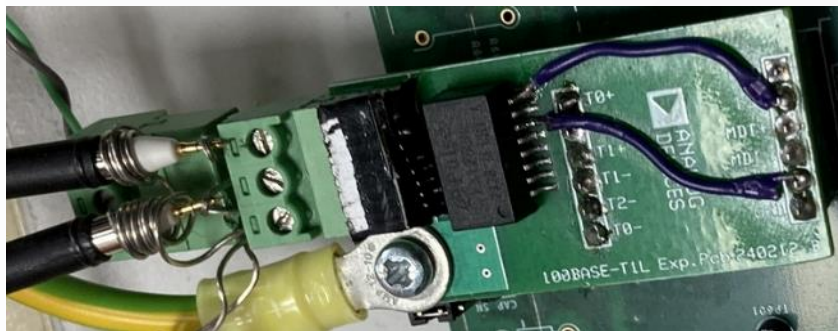
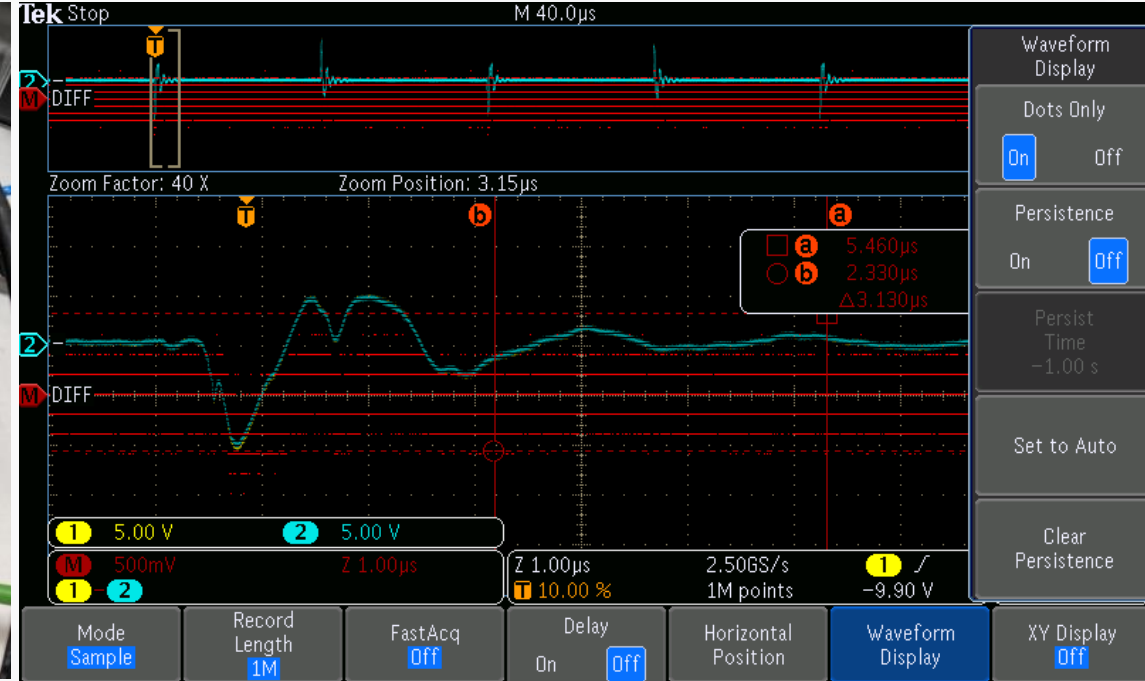
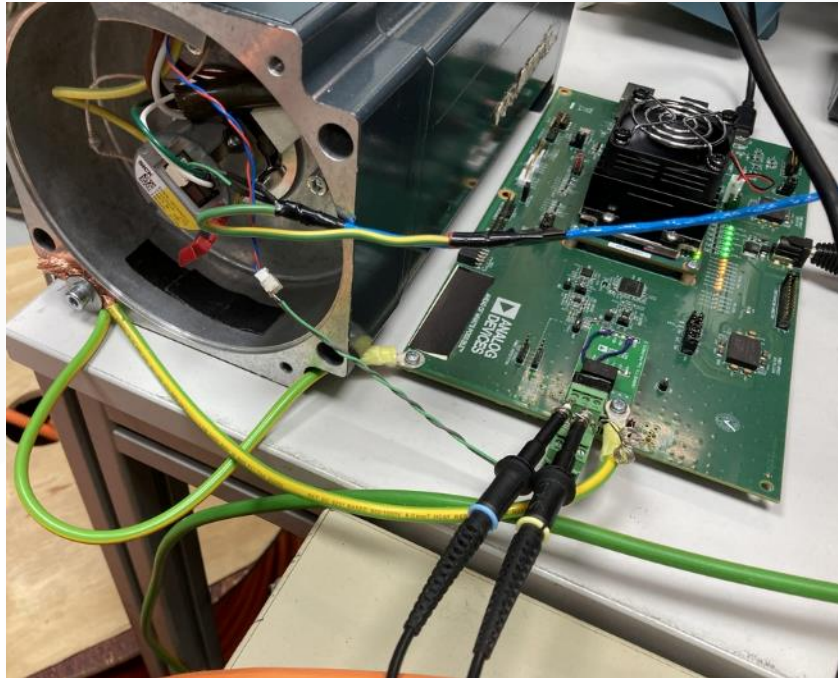


Signal Coupled to Communication Pair (Motor Side)



Oscilloscope Capture (Motor Side)

- ▶ Two single ended probes
- ▶ Good for common mode voltage (CMV) assessment
 - Signal coupled to communication line
 - CMV approx. 5V
- ▶ Not sufficient for differential signal
 - Differential signal observed using oscilloscope math subtraction
 - Oscilloscope did not have enough vertical resolution

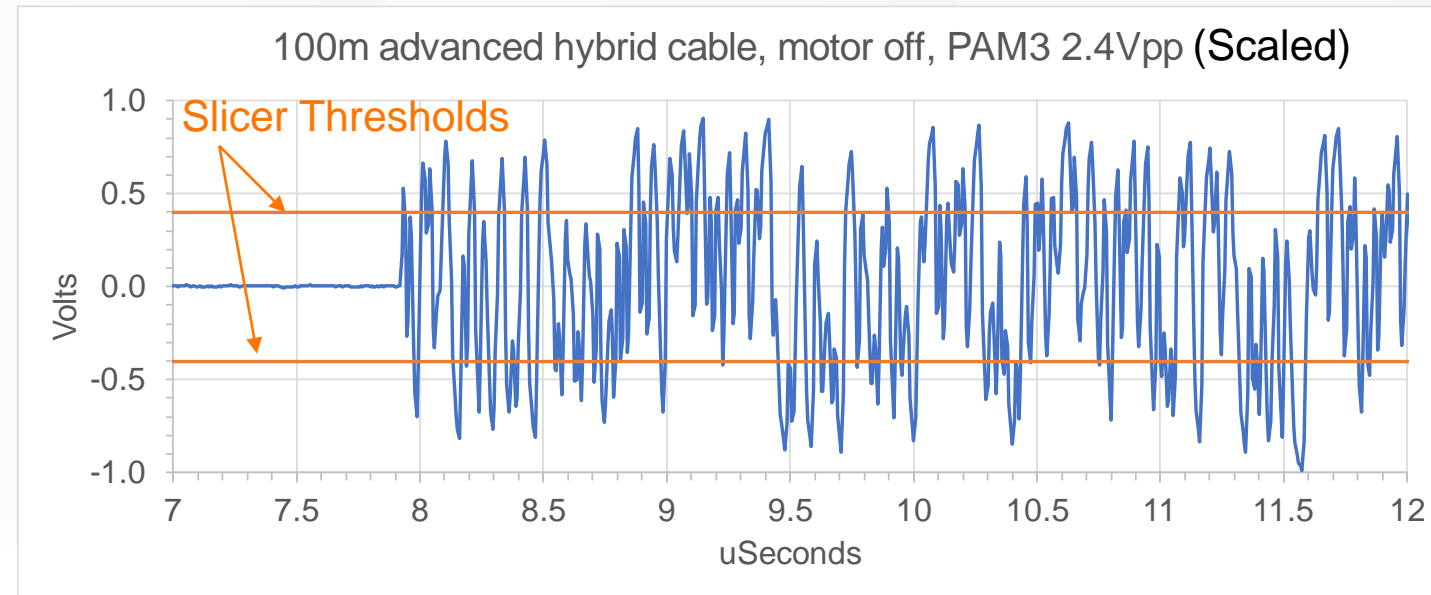
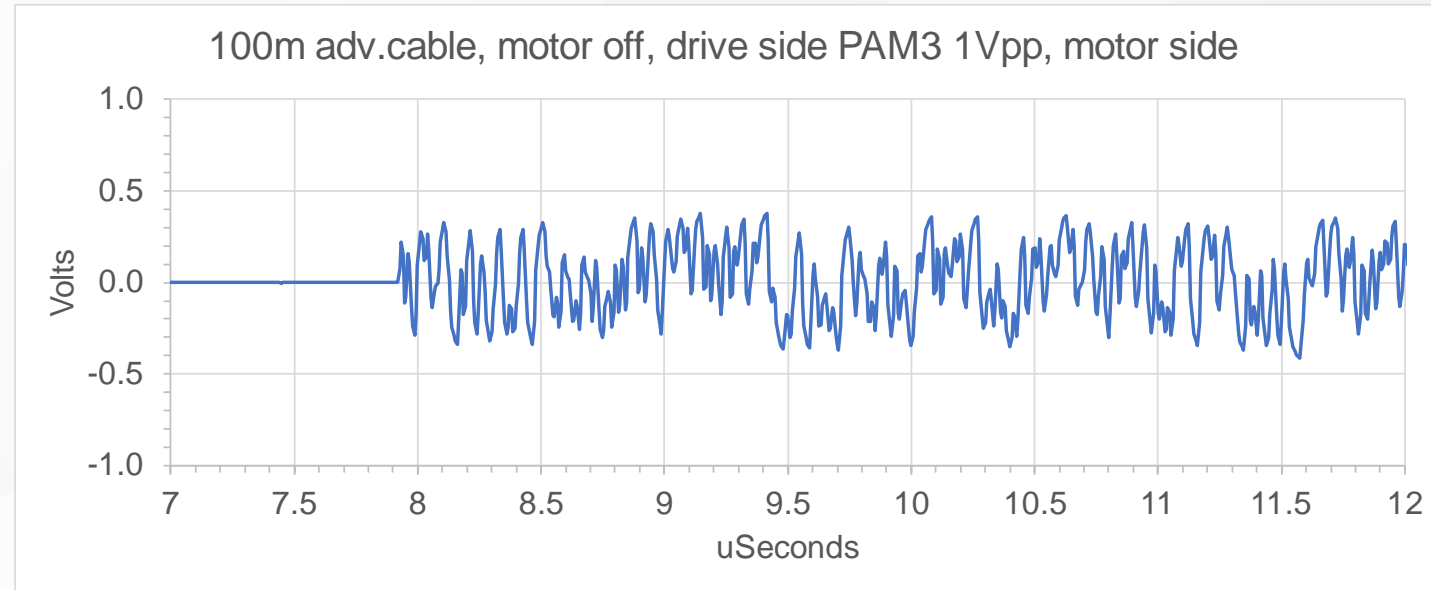


Advanced Hybrid Cable

Measurements

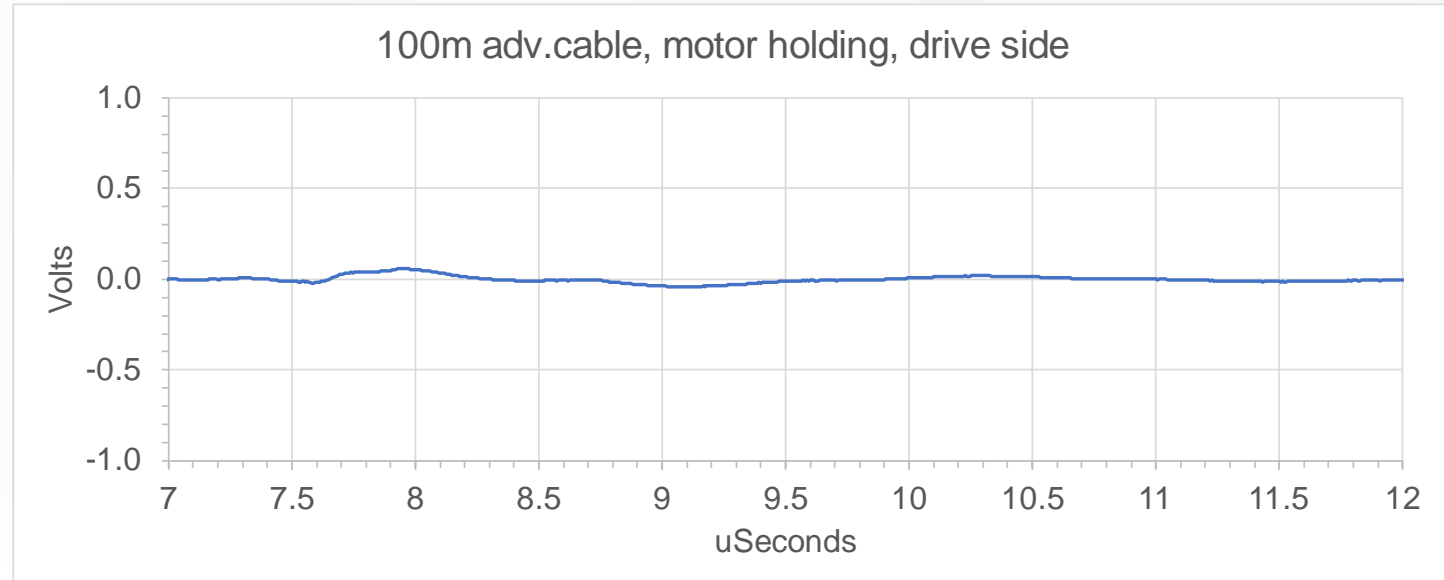
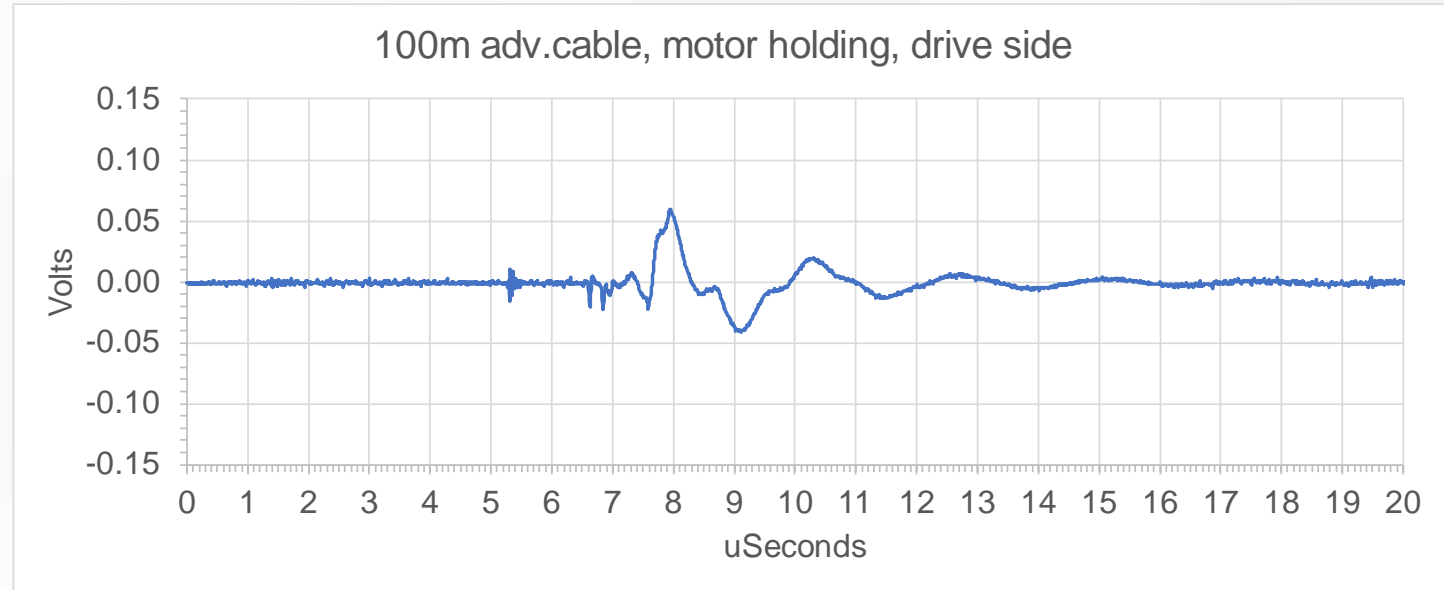
100m advanced cable - PAM3 Signal

- ▶ The Data Acquisition (DAQ) on one side of the cable transmitting PAM3 1Vpp signal
- ▶ The DAQ on the other side of cable capturing the signal
- ▶ Signal attenuated and shape changed
 - Cable frequency dependant insertion loss
 - Signal captured directly on ADC output
 - PHYs will implement digital equalisation
 - To re-shape the signal back...
- ▶ Received signal scaled (multiplied) 2.4x
 - To consider 2.4V amplitude
- ▶ Estimating / setting slicer threshold as approximately half of the received signal peak amplitude
 - Received signal approx. $\pm 0.8V$
 - Setting / showing slicer thresholds at $\pm 0.4V$

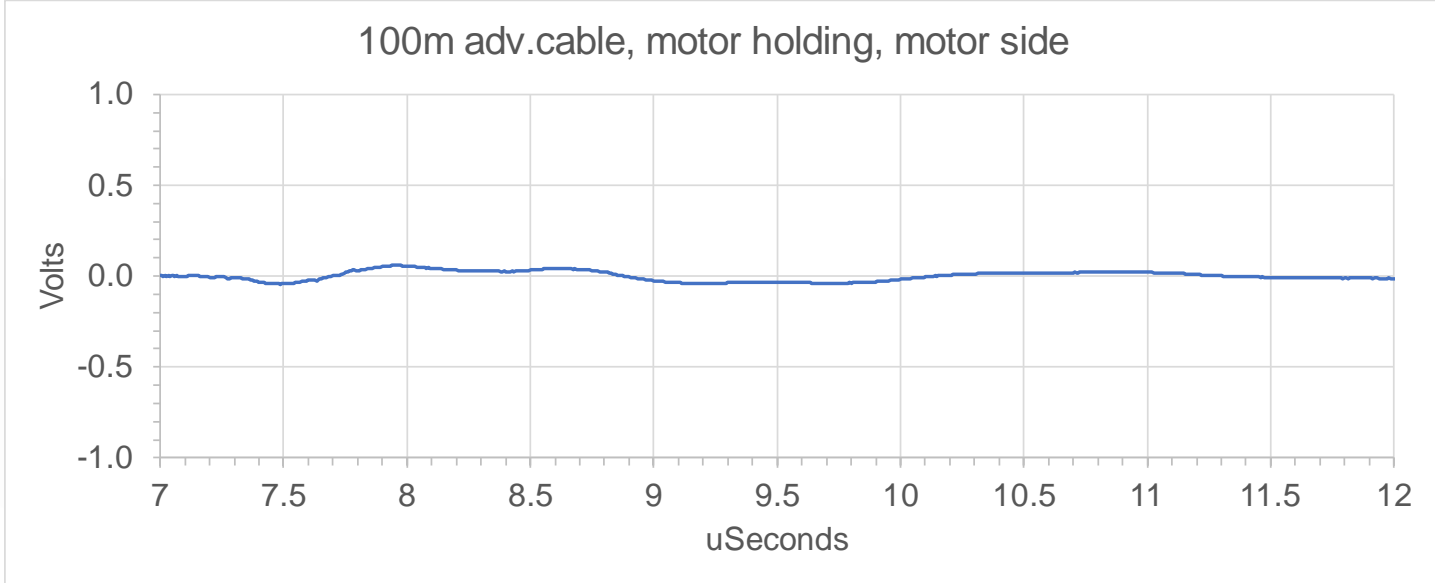
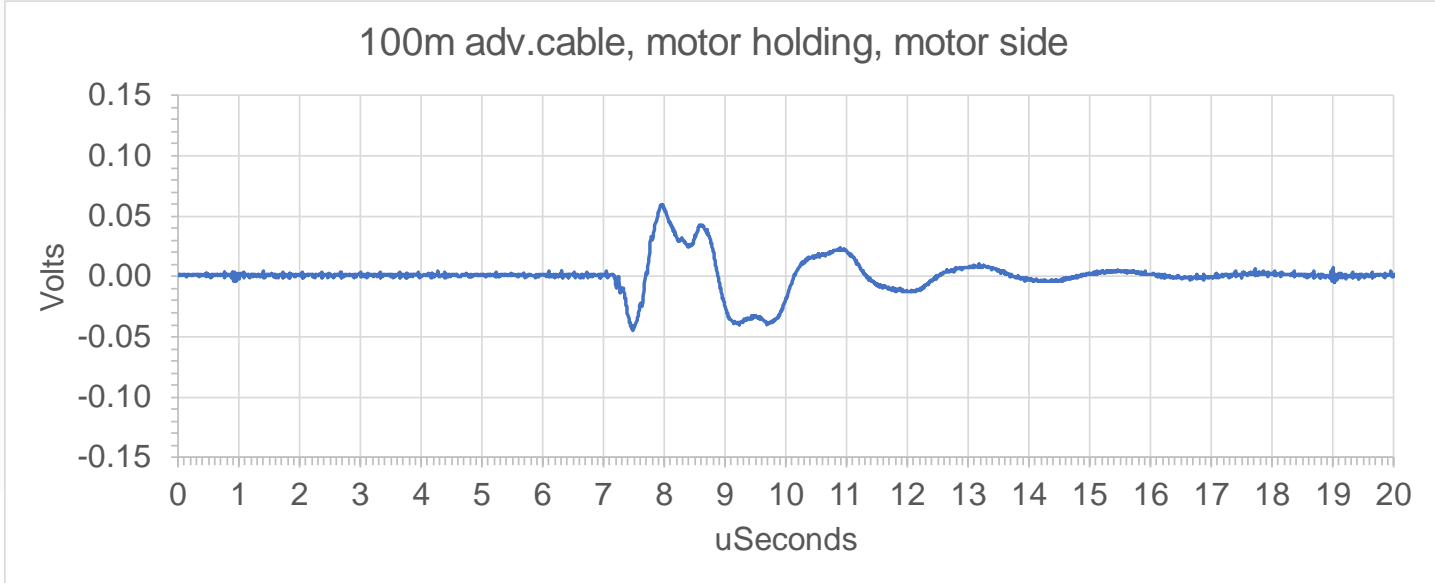


Signal Coupled to Communication Pair (Drive Side)

- ▶ The Drive outputs 3-phase PWM signal
- ▶ The Drive keeps the Motor in “hold” position
 - Motor supplied by PWM signal, but not turning
 - Identified as the worst-case condition for disturbance amplitude
- ▶ The DAQ on DRIVE side capturing the signal coupled from the PWM power lines to the communication differential pair

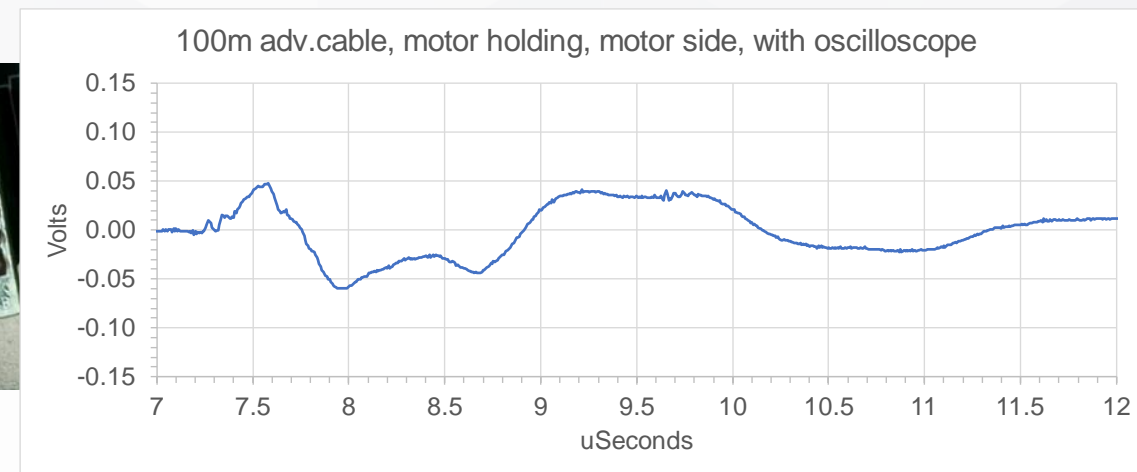
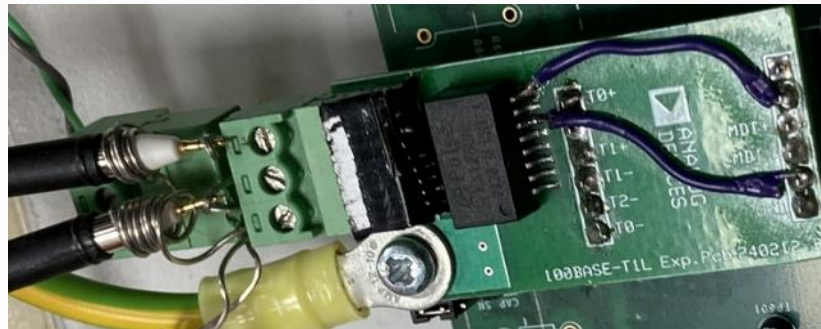
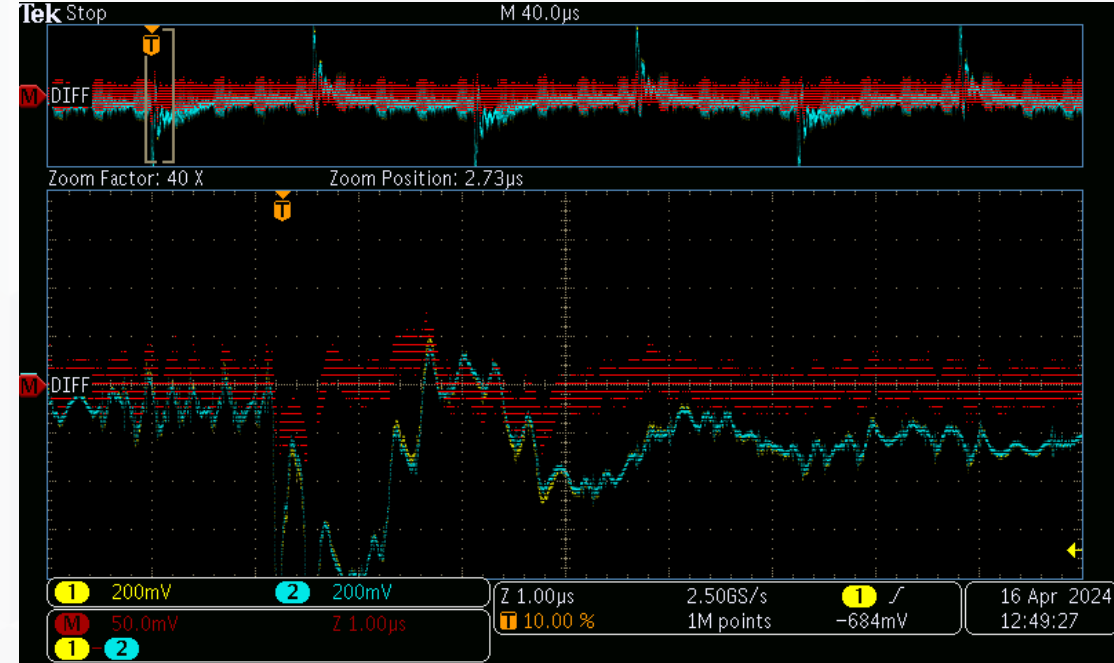
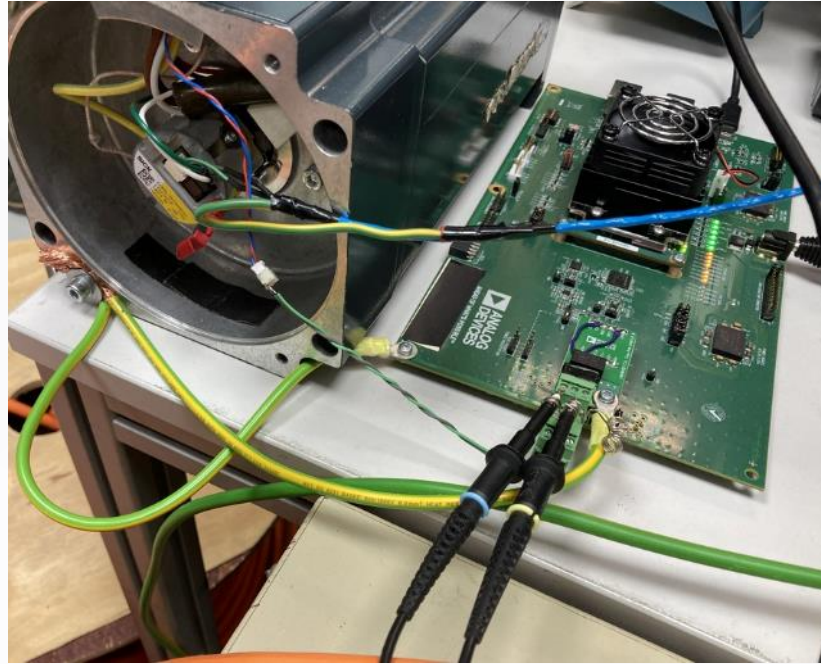


Signal Coupled to Communication Pair (Motor Side)



Oscilloscope Capture (Motor Side)

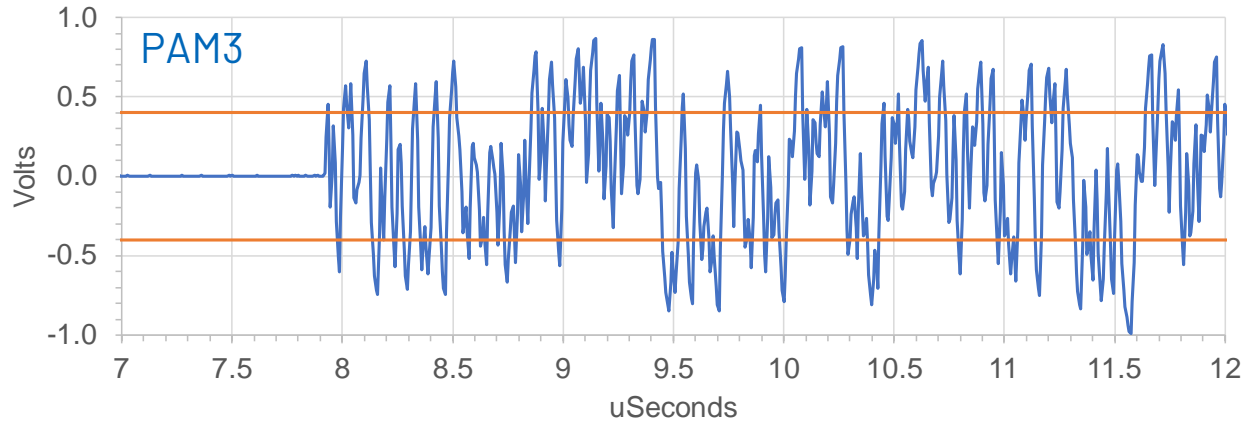
- ▶ Two single ended probes
- ▶ Signal coupled to communication line
 - CMV approx. 300mV
 - Differential signal observed using oscilloscope math subtraction
 - Oscilloscope had just (not) enough vertical resolution
 - Estimated differential signal approx. 50mV
- ▶ .



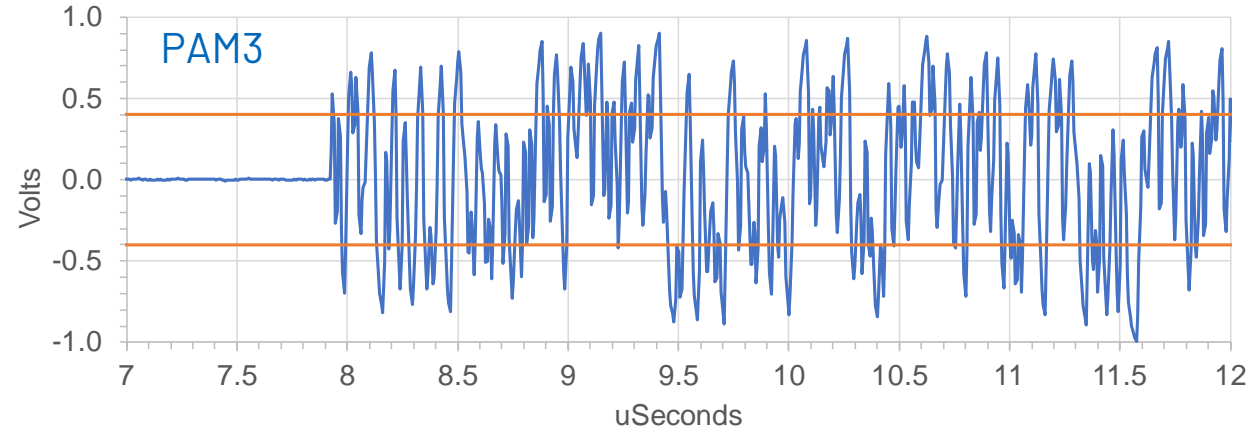
Discussion

Discussion

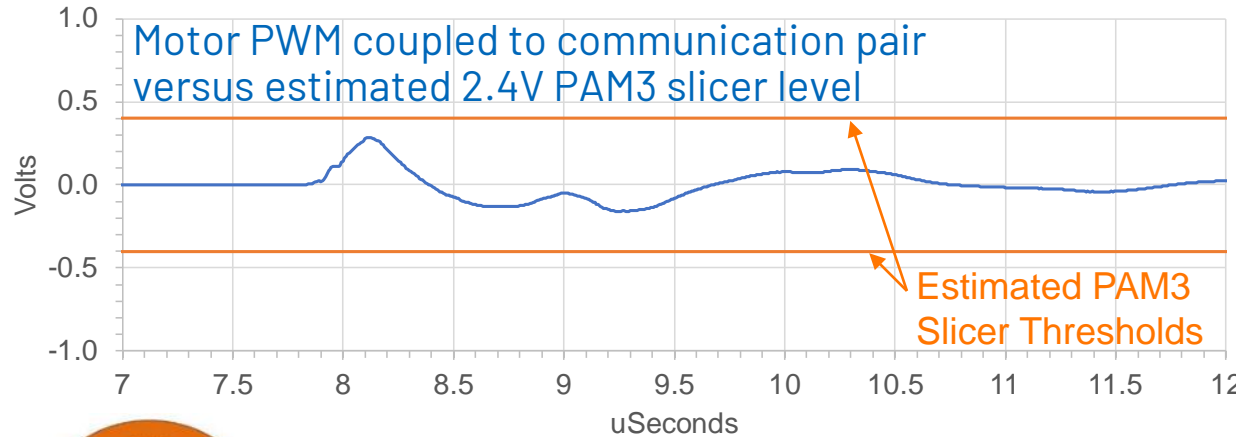
100m standard hybrid cable, motor off, PAM3 2.4Vpp



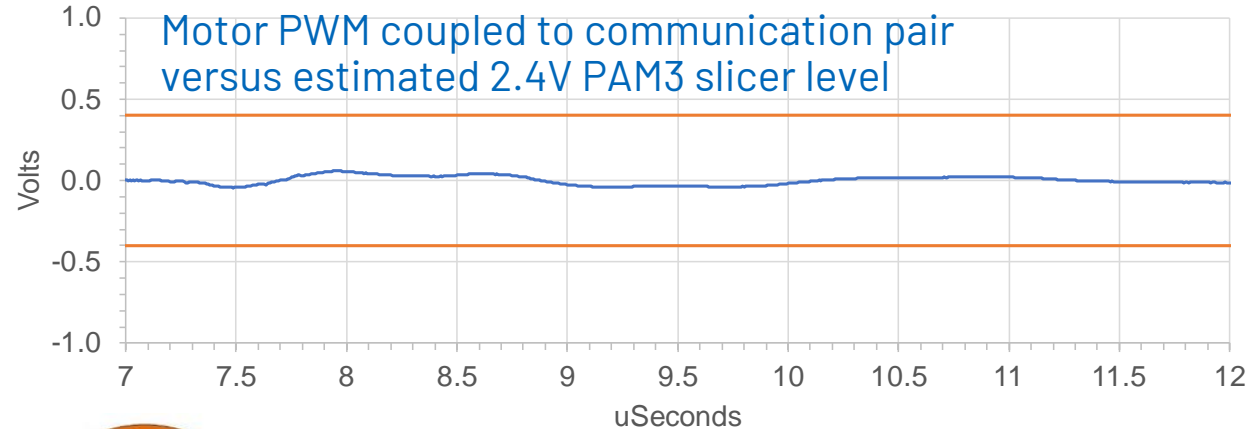
100m advanced hybrid cable, motor off, PAM3 2.4Vpp



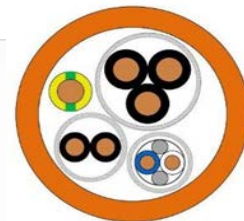
100m standard hybrid cable, motor holding



100m advanced hybrid cable, motor holding



100m "Standard" Hybrid Cable
Estimated a small margin at PAM3 2.4V



100m "Advanced" Hybrid Cable
Estimated a good margin at PAM3 2.4V

Thank You

Questions?