Communication interference from Motor PWM variants within hybrid cables

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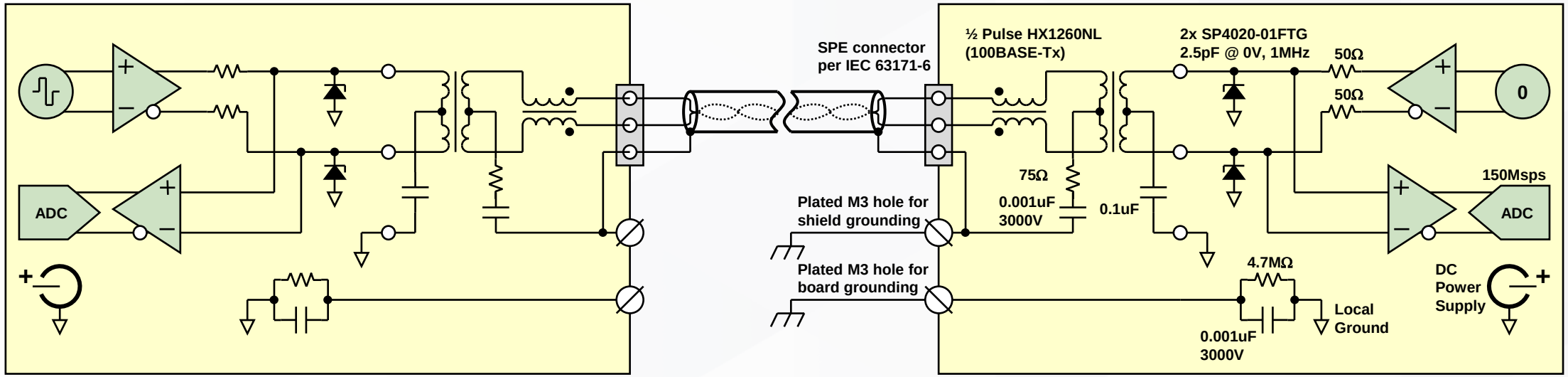
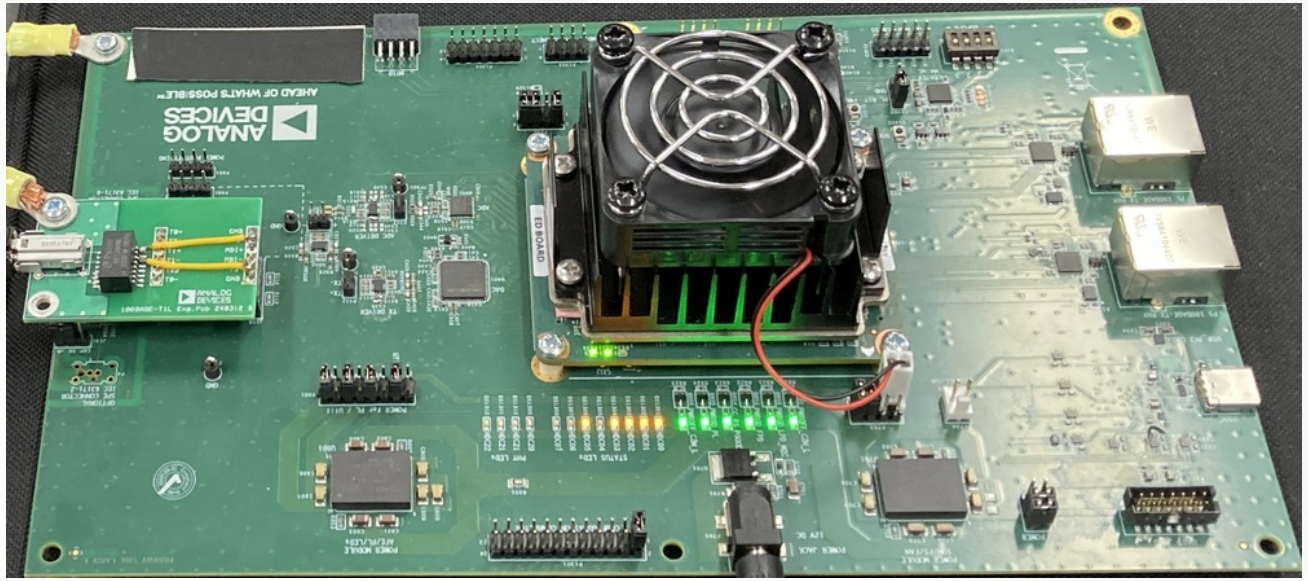
Communication interference from Motor PWM variants within hybrid cables

- Setup
  - Data Acquisition (DAQ) system
  - Hybrid Cables
- Variant 1
  - Setup description
    - ArmorKinetix Distributed Servo Drive (DSD)
    - 50ns rise/fall time, 3m max hybrid cable length
  - PAM3 signal
  - PWM coupled to the SPE line
    - Grounding configurations
  - Oscilloscope capture
- Variant 2
  - Setup description
    - Kinetix 5700 Dual Axis Inverter
    - 200ns rise/fall time, 90m max hybrid cable length
  - PAM3 signal
  - PWM coupled to the SPE line
  - Oscilloscope capture
- Discussion
  - Signal to pulse noise margin

The motor windings must be protected
from the PWM reflections increasing the voltage
- by limiting the rise/fall time in proportion to the cable length.

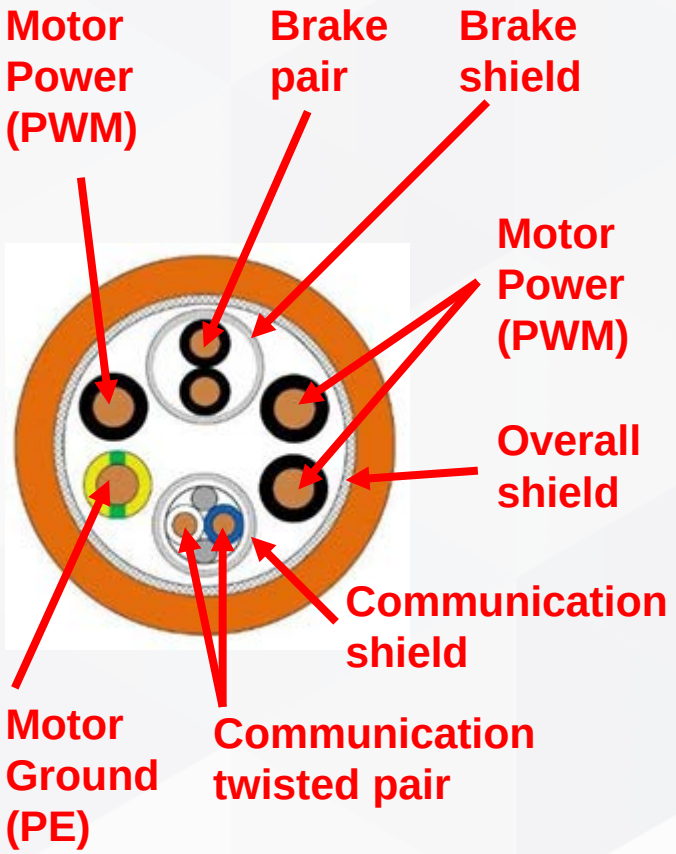
Data Acquisition (DAQ) used for measurements





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
- FFE[4G2,5+(2x1)ST/N+(2xAWG22)ST/SN/RE]ST/PUR



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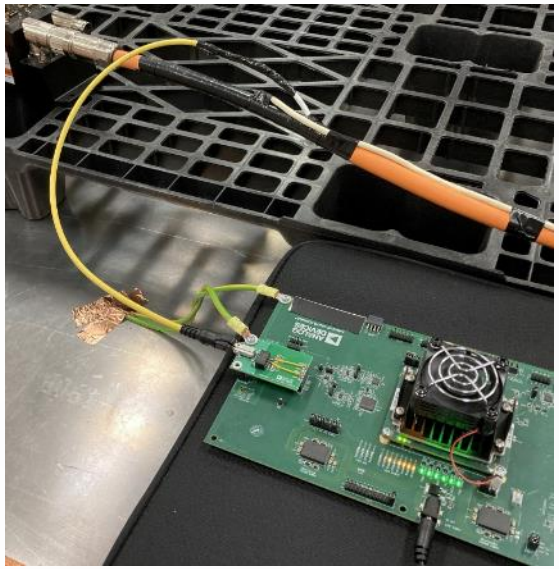
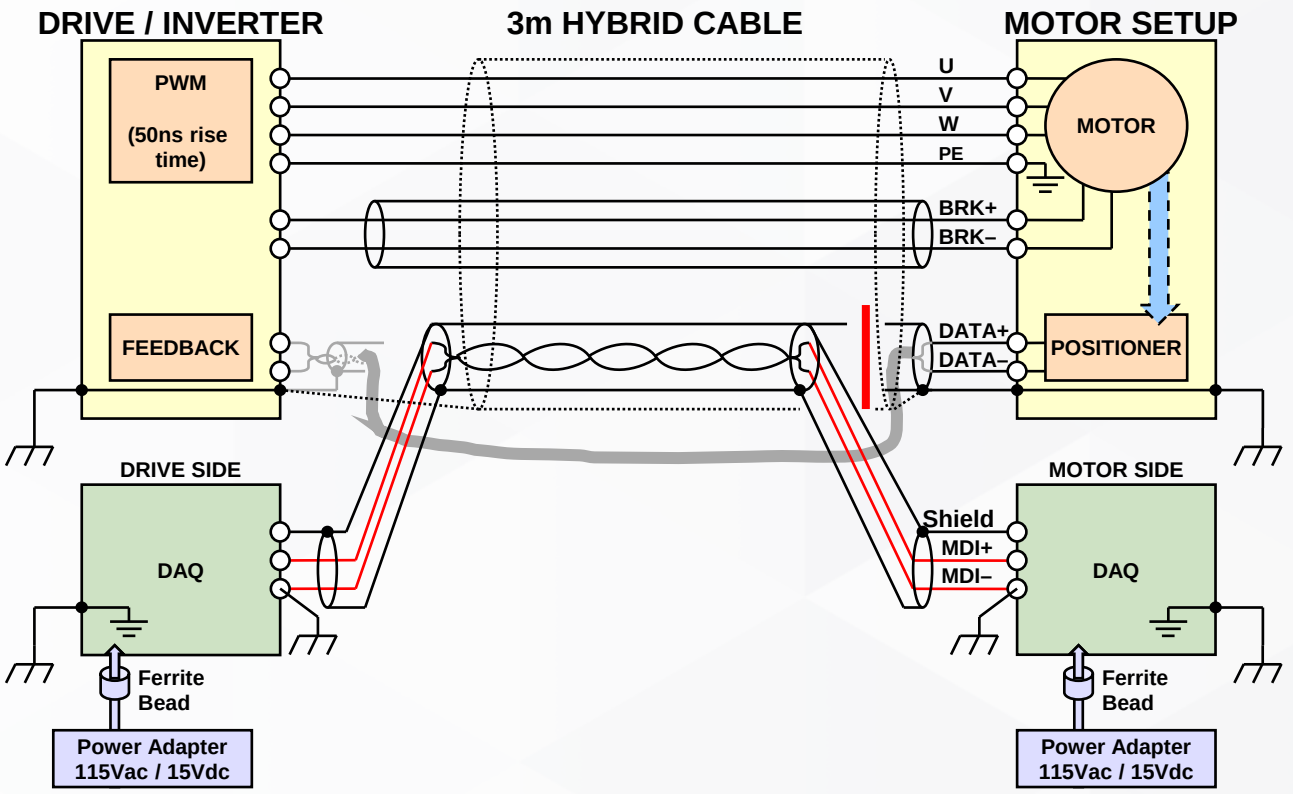
Variant 1
ArmorKinetix
Distributed Servo Drive (DSD)

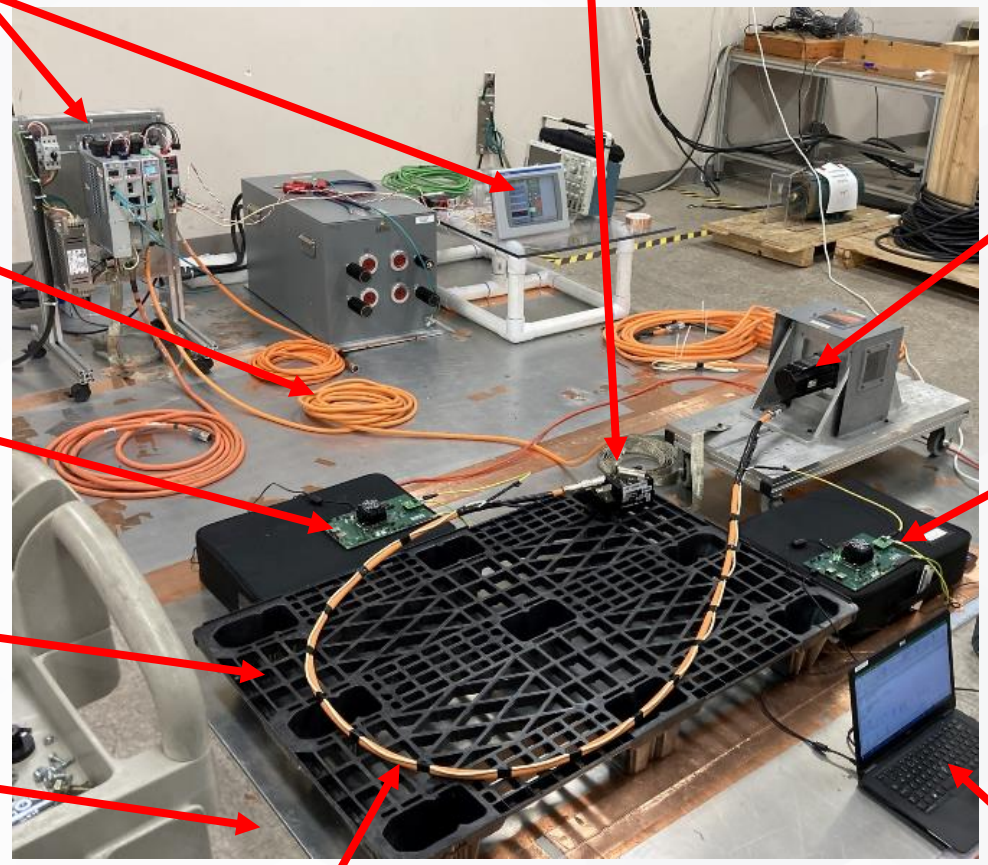
ArmorKinetix Distributed Servo Drive (DSD)





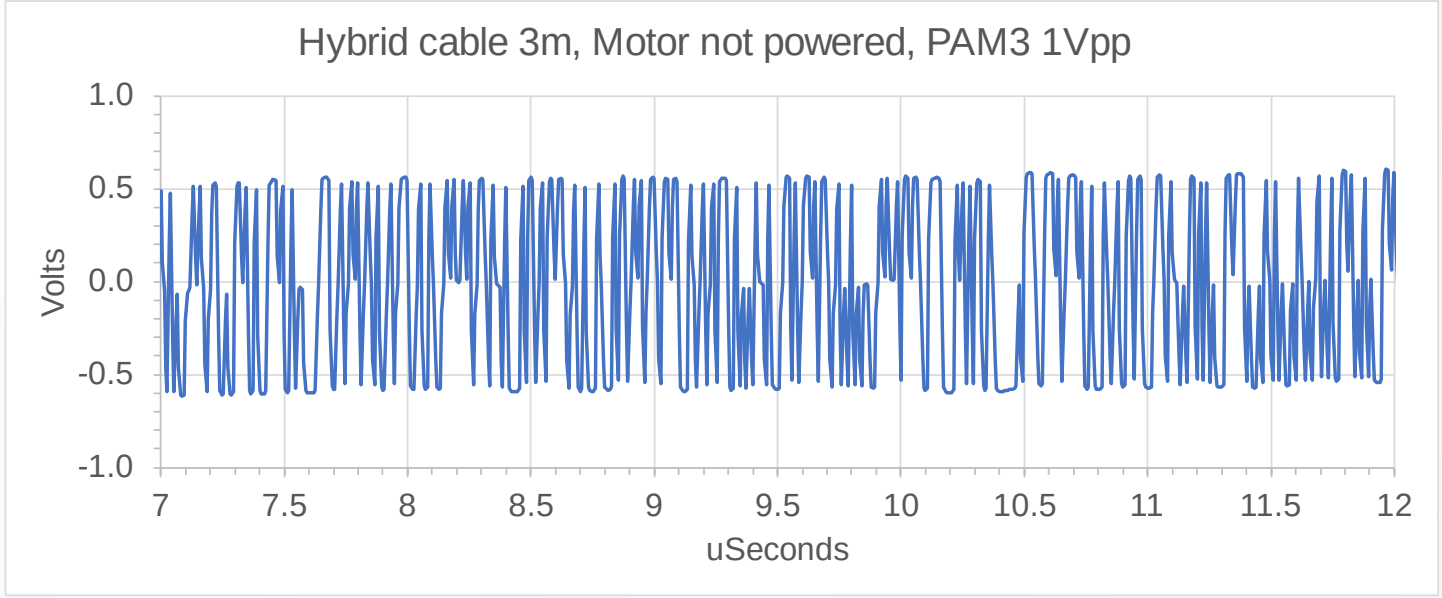
ArmorKinetix Distributed Servo Drive (DSD)

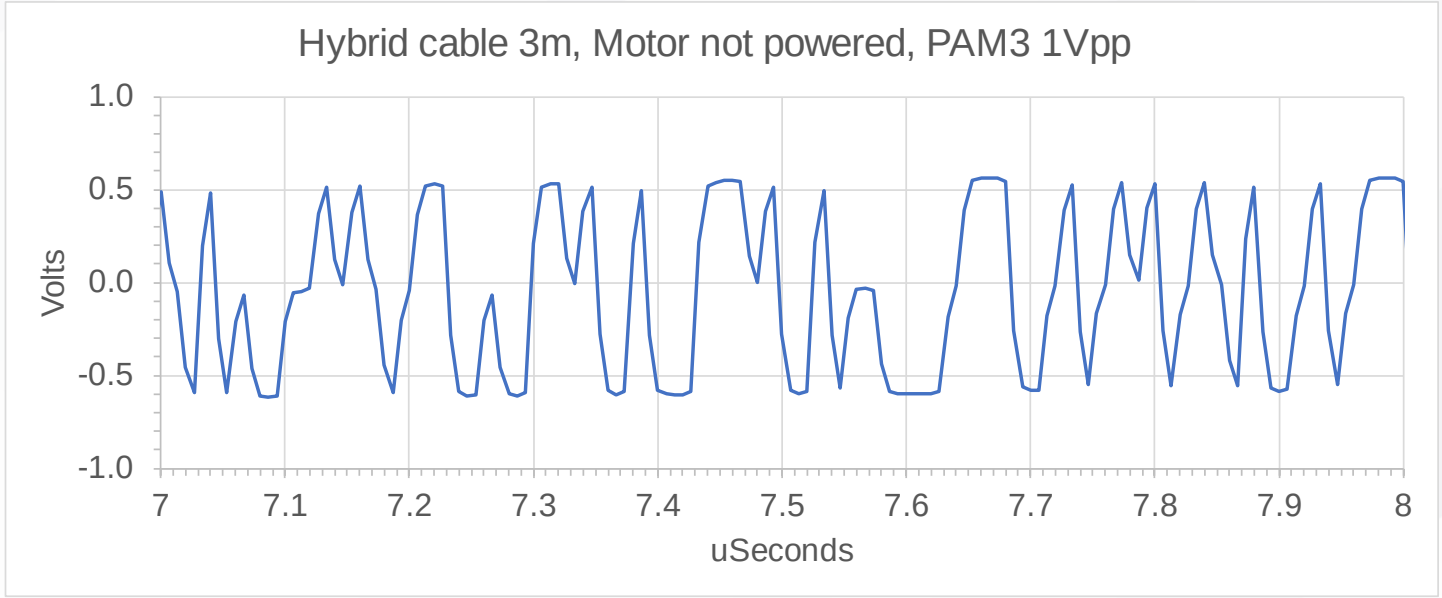
- PWM with 50ns rise time
- 3m Hybrid Cable
- DAQ pair measures coupled PWM interference at each end
- Drive controls PWM to motor
  - Held in position at zero speed is worst case
- PC uses USB to attach to each DAQ to collect measurement



PAM3 1Vpp Signal

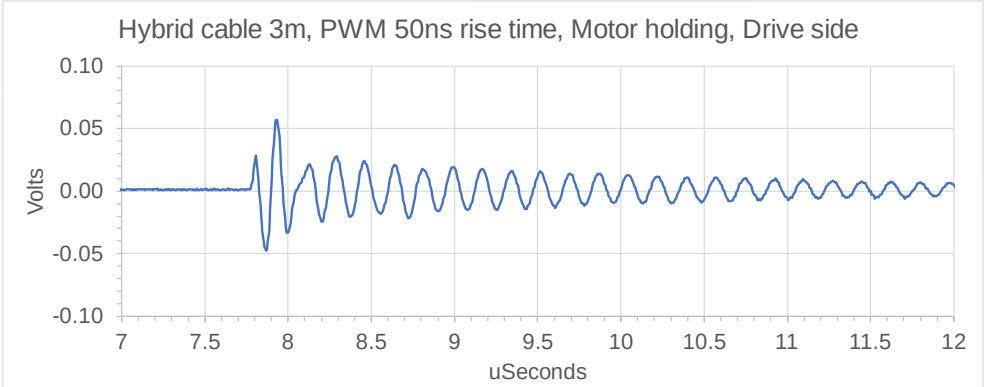
- The Data Acquisition (DAQ) on one side of the cable transmitting PAM3 1Vpp signal
- The DAQ on the other side of cable capturing the signal
- No visible attenuation / distortion of the signal on 3m hybrid cable

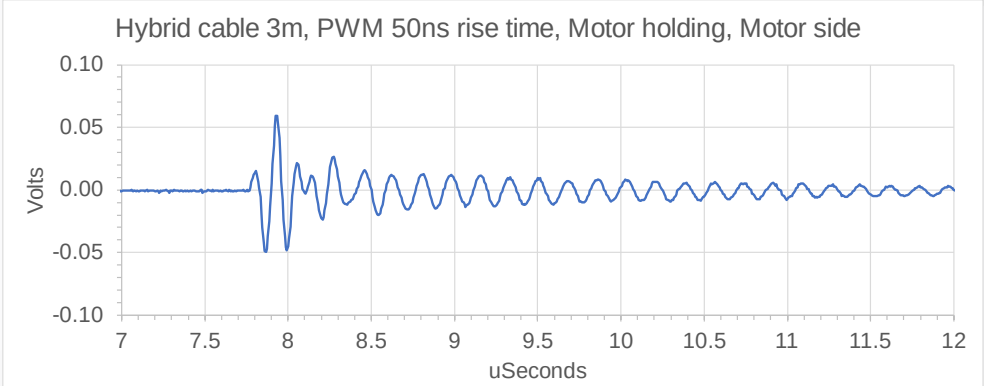


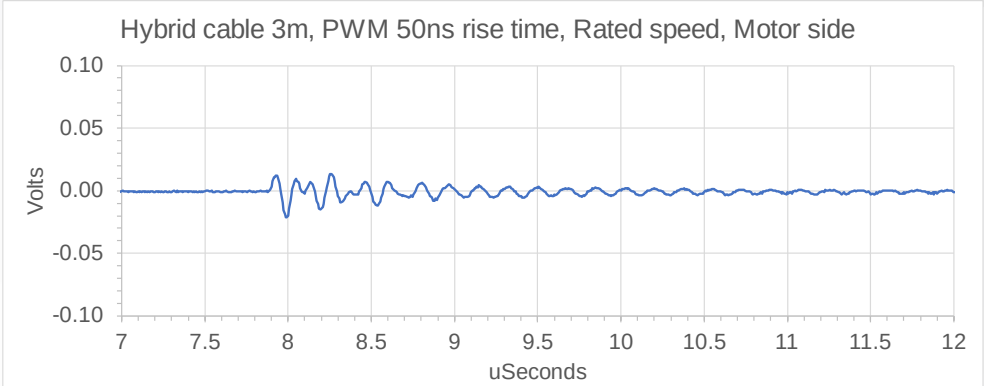


Signal Coupled to Communication Pair

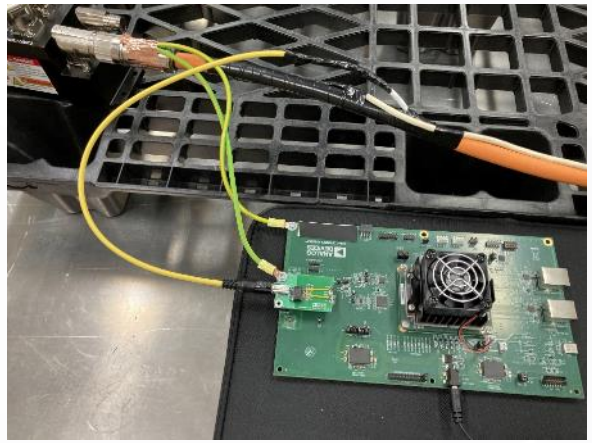
- The Drive outputs 3-phase PWM signal
- The Drive keeps the Motor in “hold” position
  - Motor supplied by PWM signal, but not turning
  - Identified as the worst-case condition
- The DAQ on both sides capturing the signal coupled from the PWM power lines to the communication differential pair
- The bottom capture is the same setup
- The Motor is turning the (max.) rated speed
  - The signal coupled to the communication pair is much lower amplitude

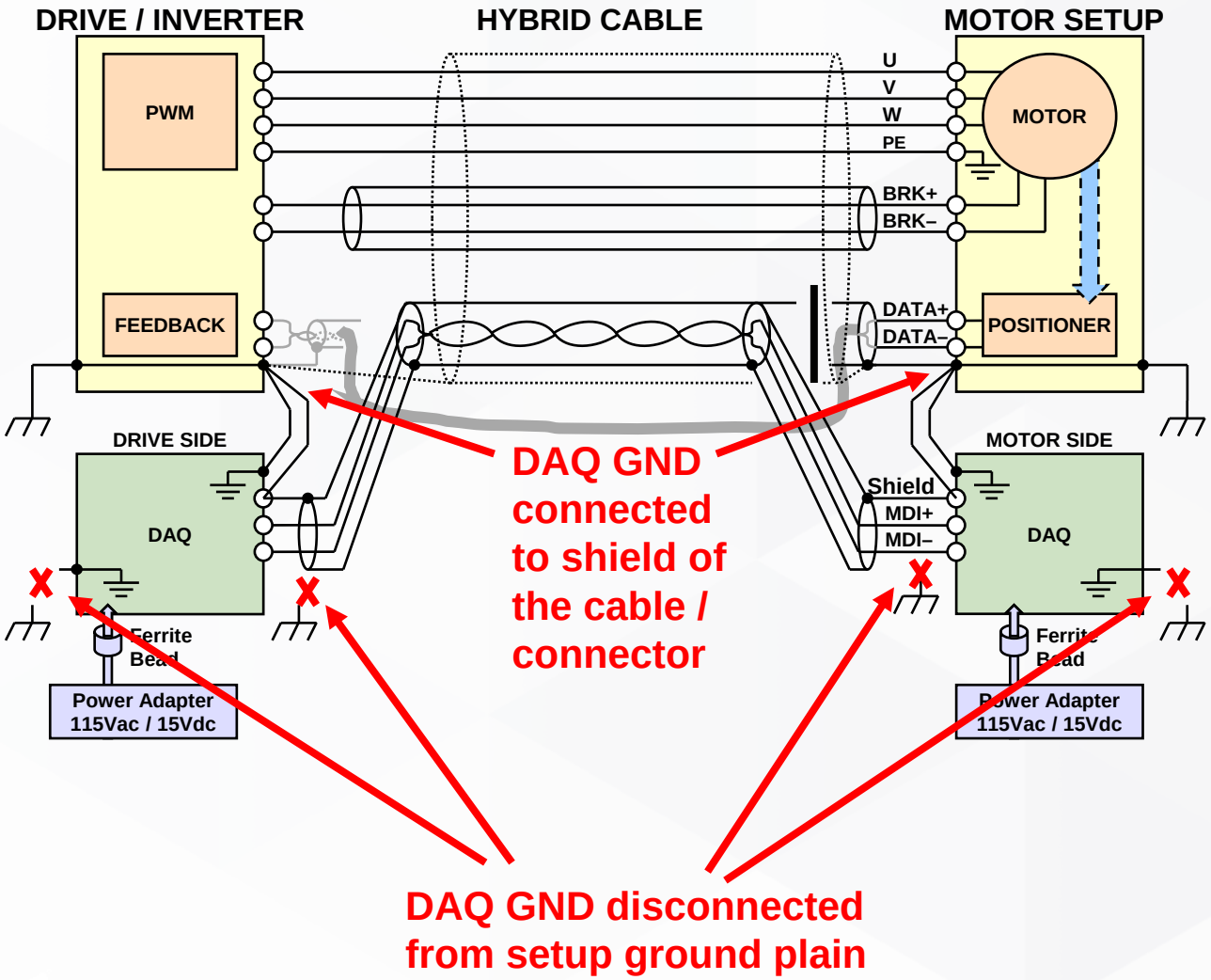


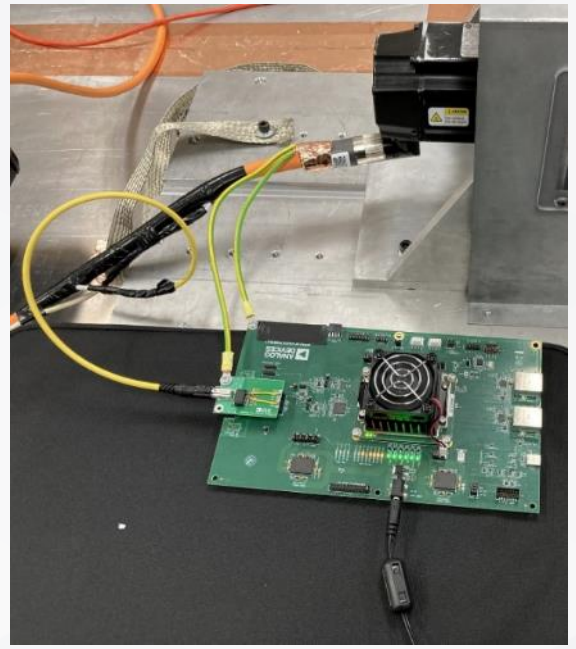




Change in grounding – DAQ GND to cable GND

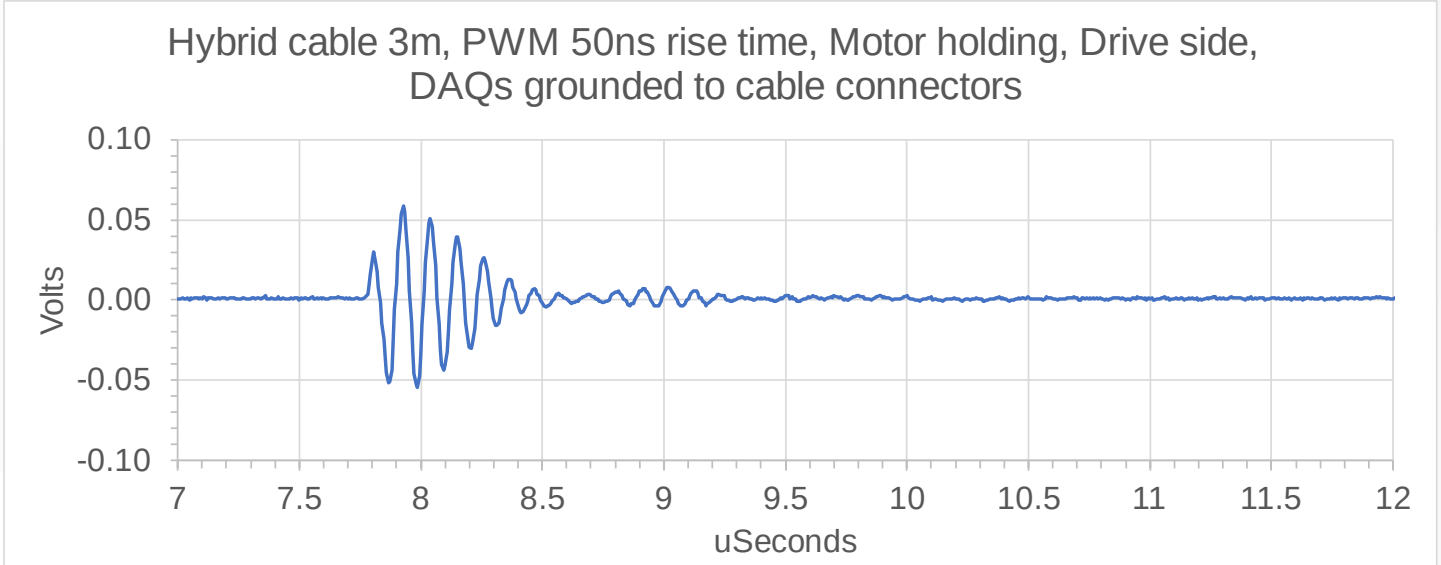


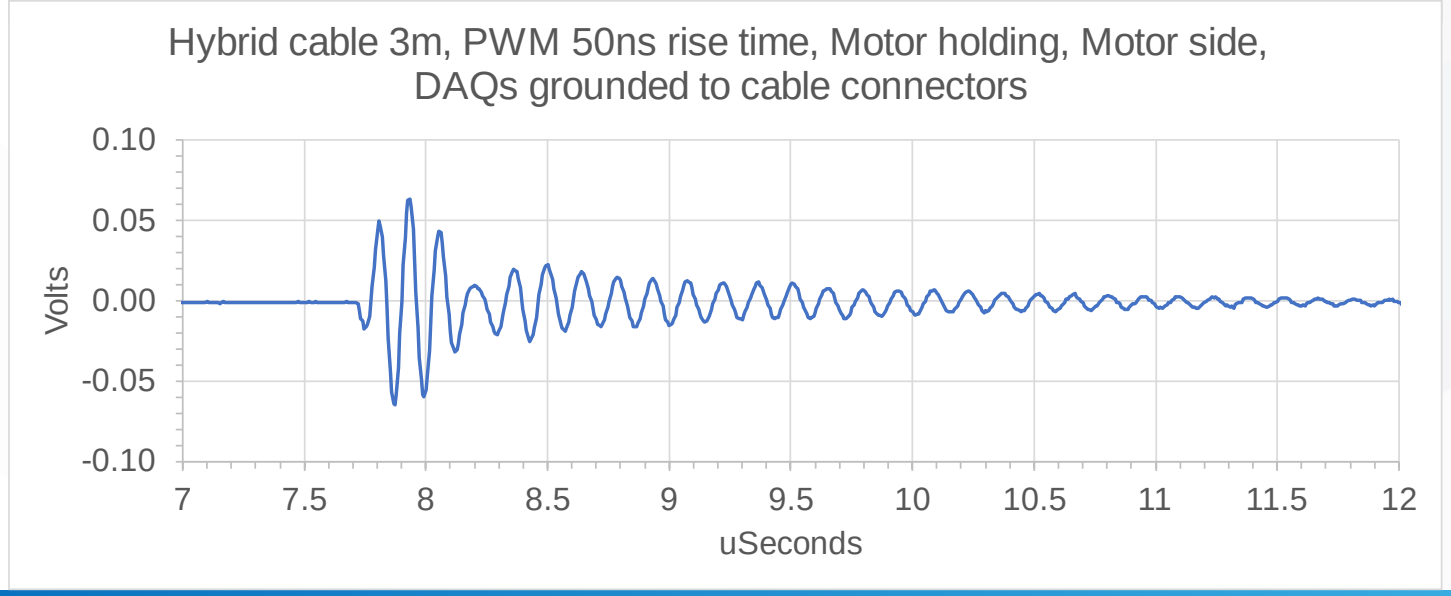




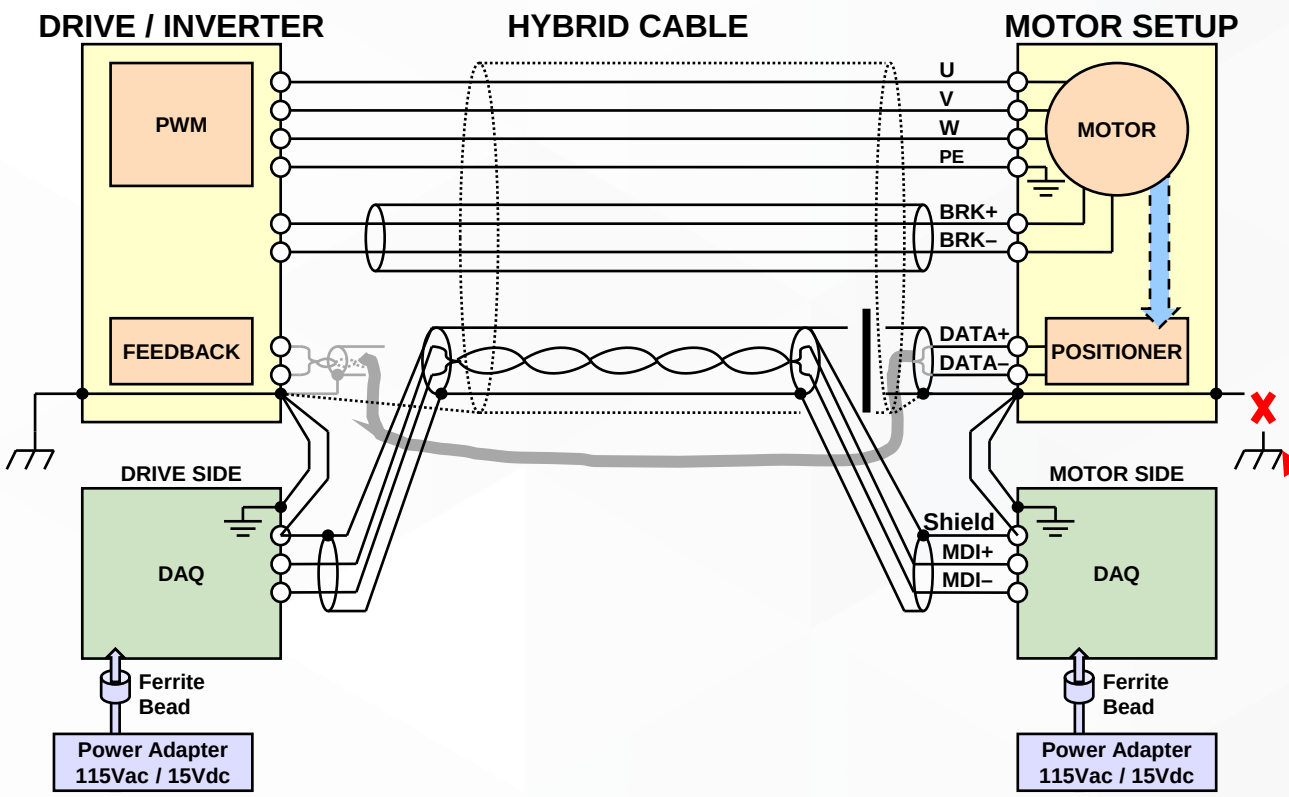
Signal Coupled to Communication Pair

(Change in grounding – DAQ GND to cable GND)

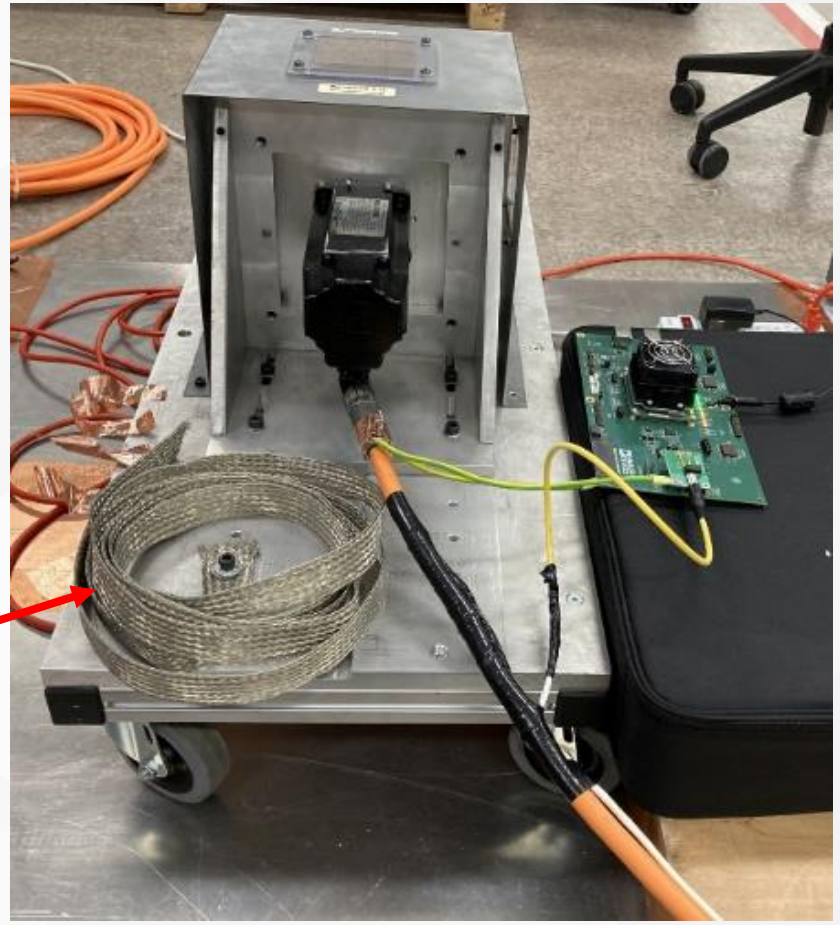




Change in grounding – Motor GND only via cable

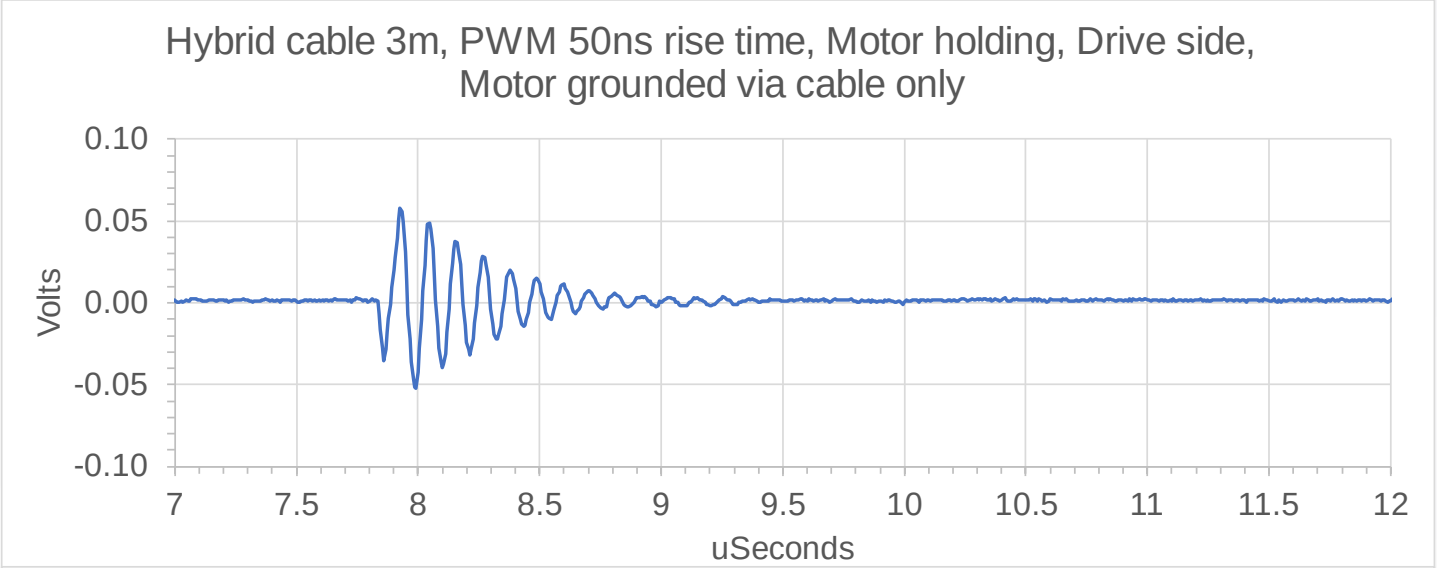


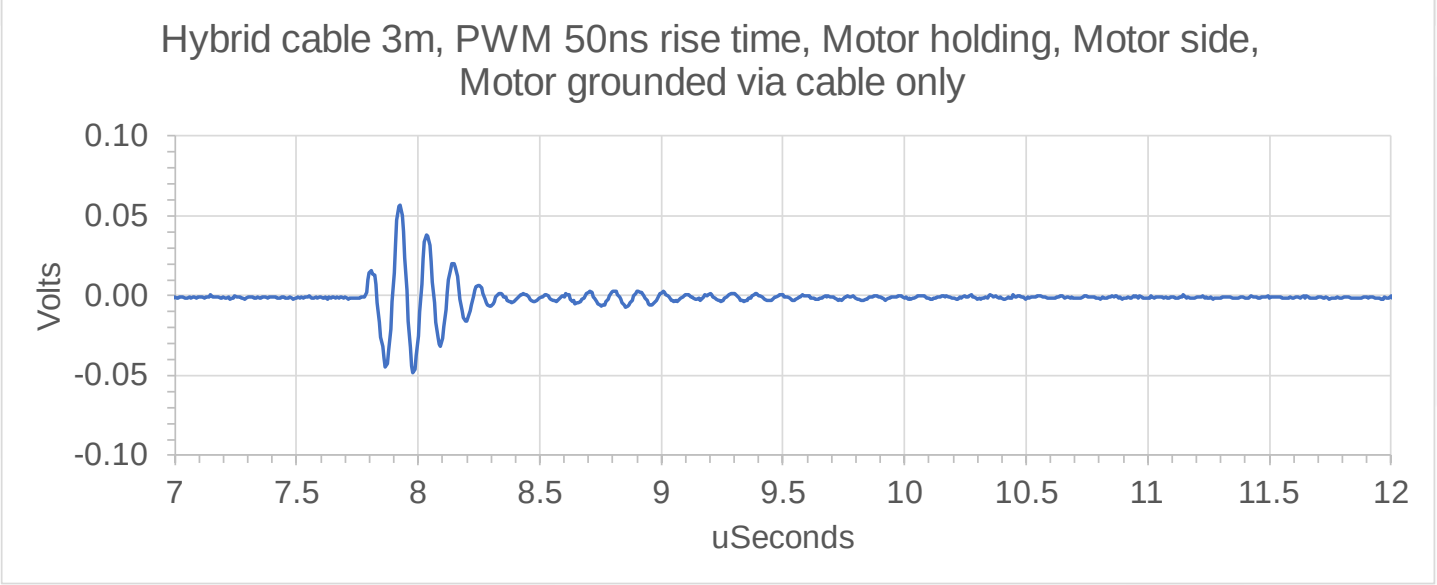
Motor GND disconnected from setup ground plain



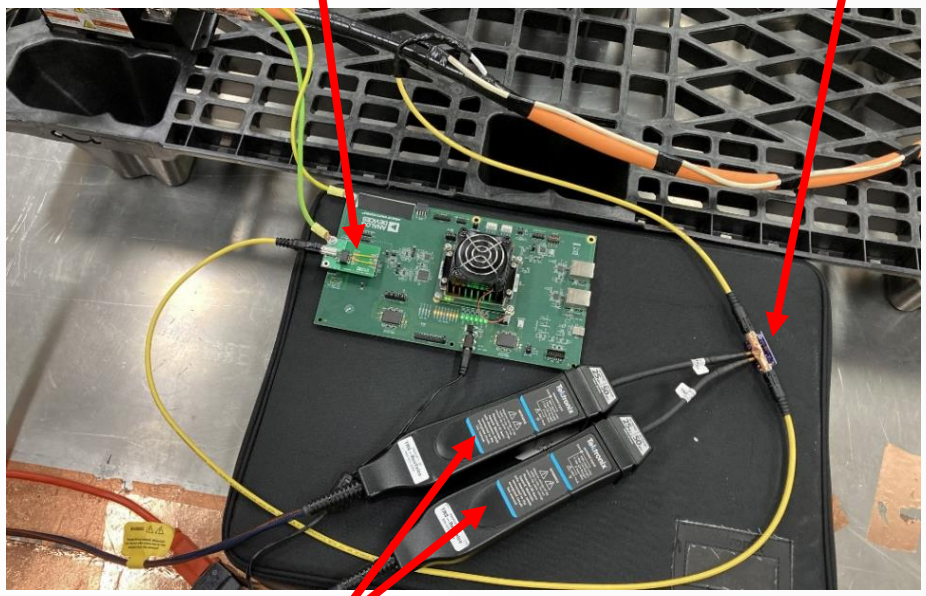
Signal Coupled to Communication Pair

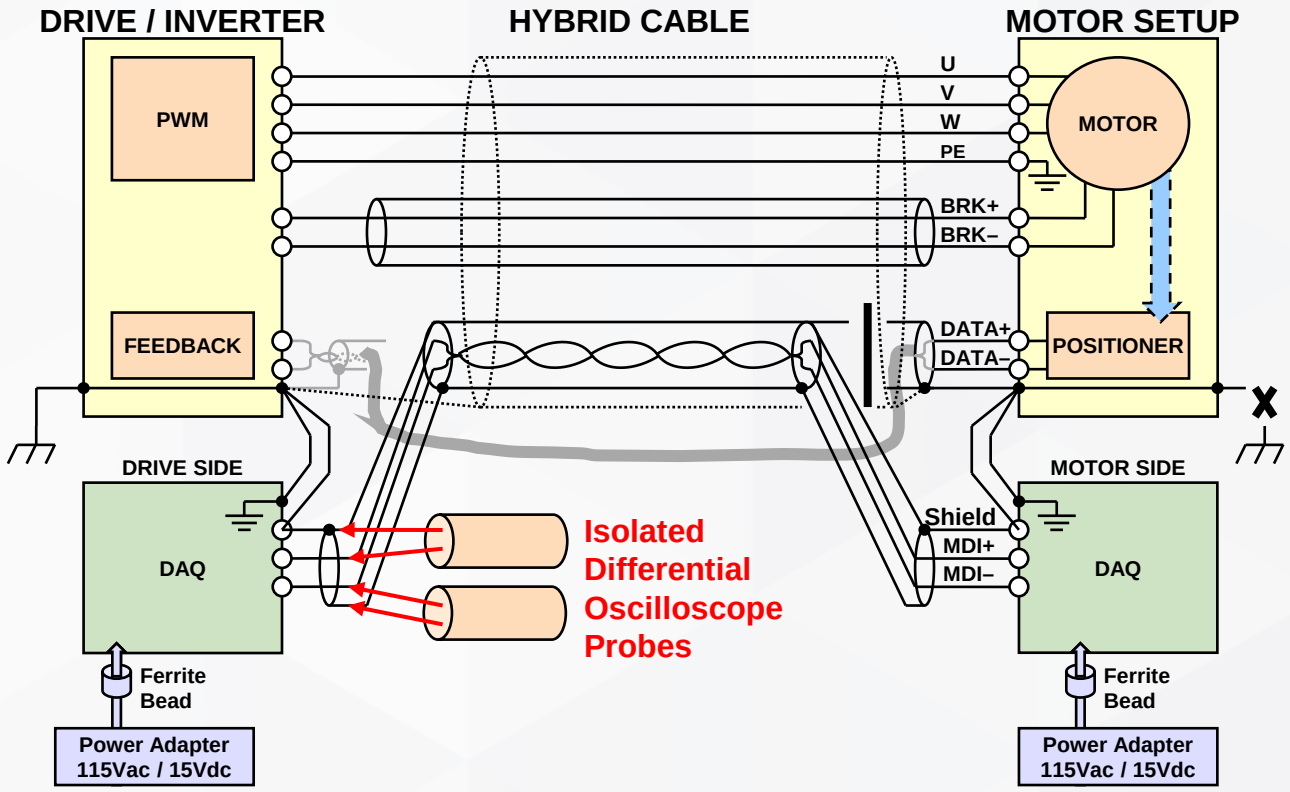
(Change in grounding – Motor GND only via cable)





Oscilloscope Captures (ArmorKinetix, 3 m, 50 ns)





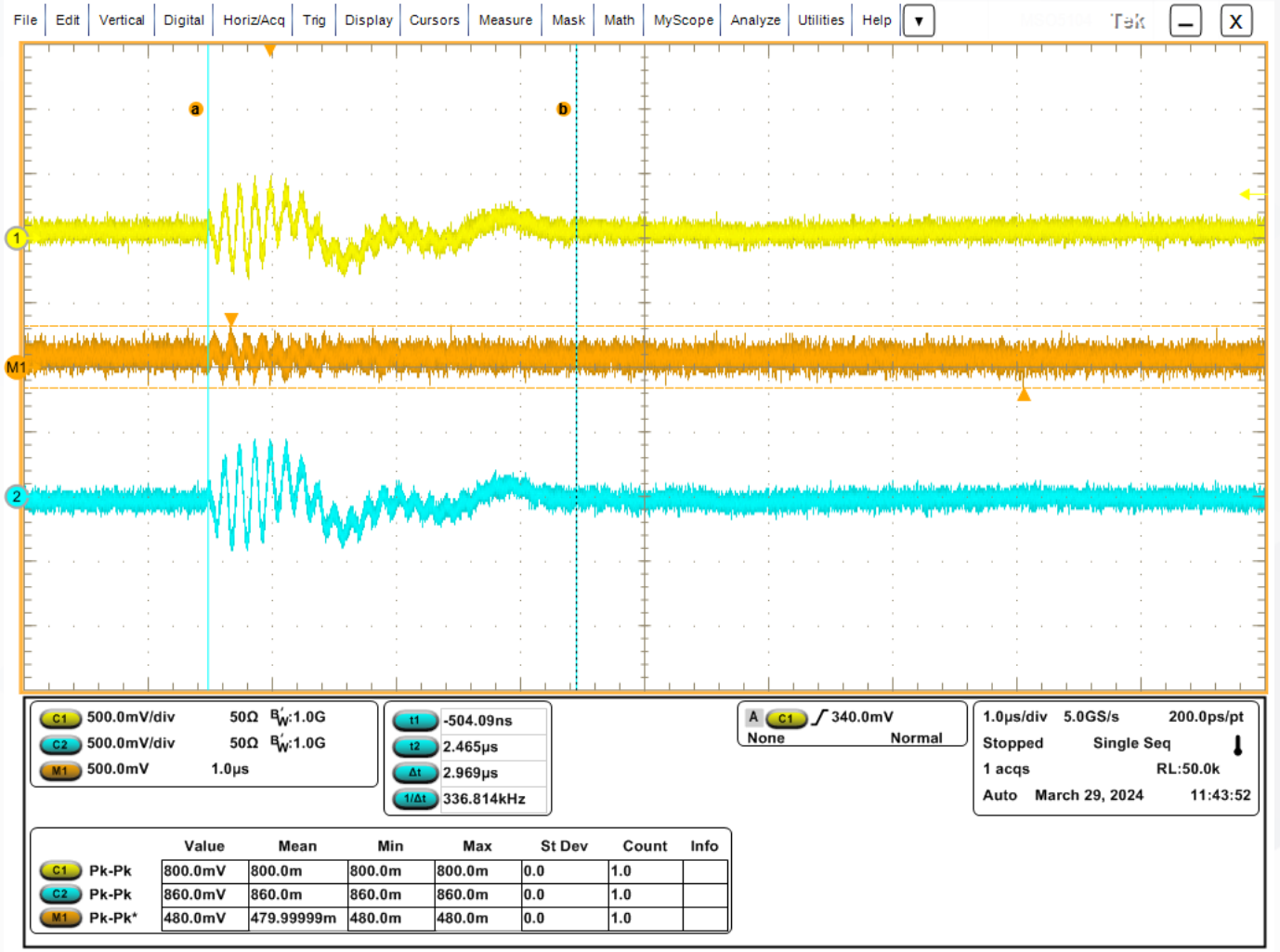
- CH1 and CH2 each measure CM to shield at SPE +/-
- Scope M1 calculates DM
- Allows line-side and PHY-side comparison

Oscilloscope Capture – PWM

- Wide capture without ADI test pattern to confirm presence of PWM
  - DAQ has limited storage
- PWM transients every 125 us

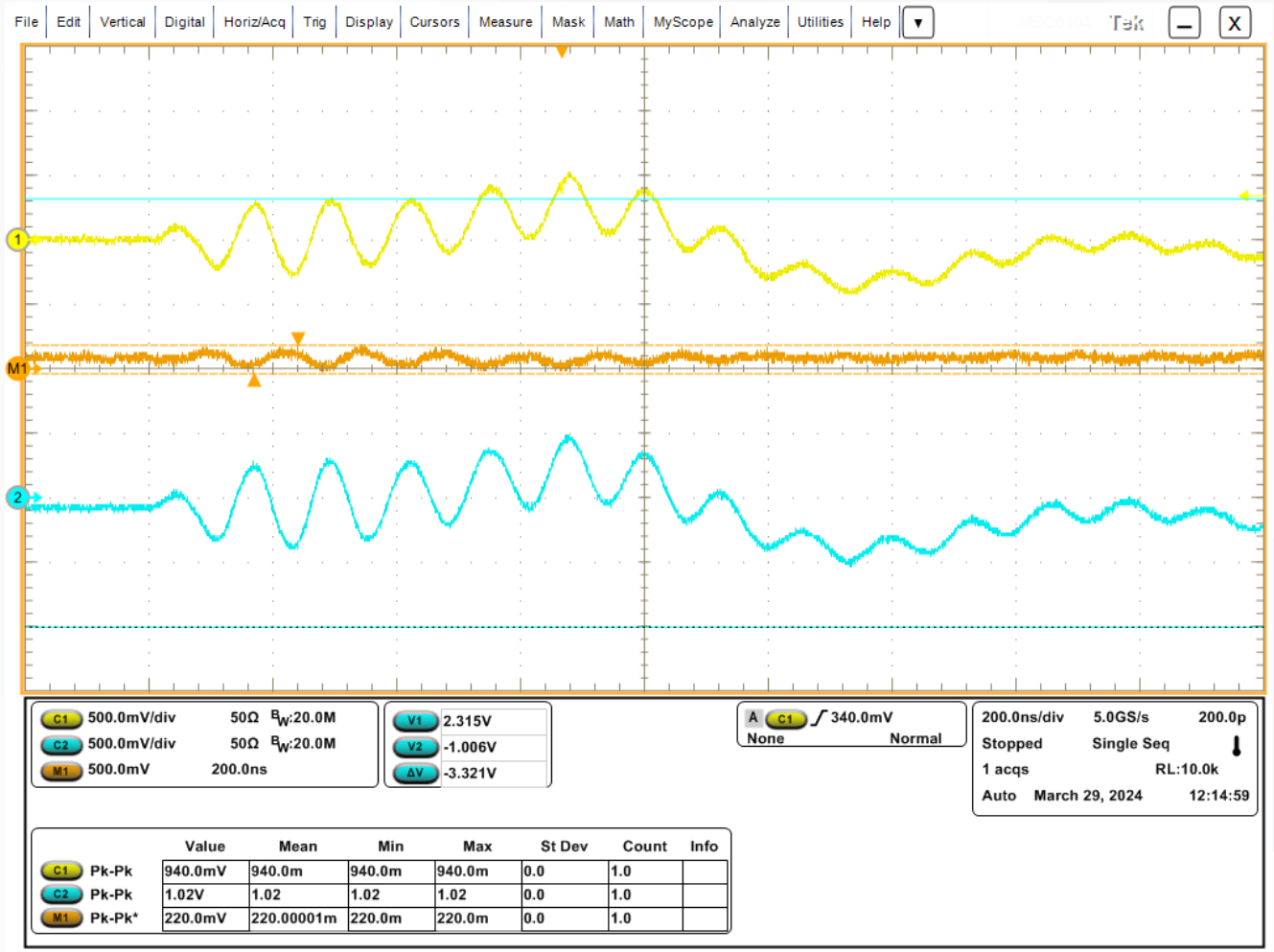
Oscilloscope Capture – PWM

- ArmorKinetix with 3 m cable
- Short capture to see single PWM event
  - Without ADI test pattern
- PWM pulses response persists for > 3 us
- Oscilloscope filters @ 1 GHz
  - DM measures less than CM by ~2x
  - M1 = 480 mVpp **exceeds** amplitude at DAQ



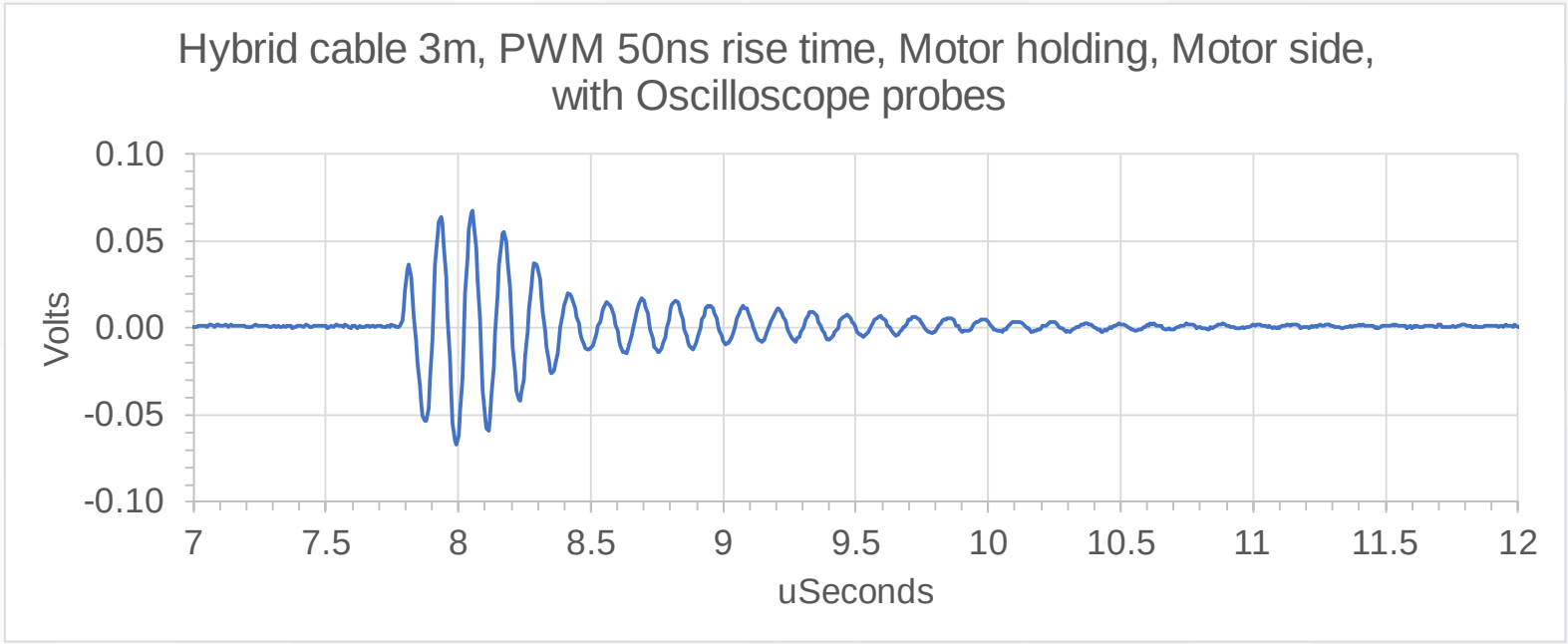
Oscilloscope Capture – PWM

- ArmorKinetix with 3 m cable
- Short capture to see oscillations in single PWM event
  - Without ADI test pattern
- Oscilloscope filters @ **20 MHz**
  - It was presumed that the HF interference ADDED to the desired signal to create mismatch of the oscilloscope measurement with the ADI board (which has some HF filtering)
  - DM measures less than CM by ~5x
  - M1 = 220 mVpp better matches amplitude at DAQ
- Oscillations are ~125 ns (8 MHz)
  - Relates to cable electrical length



Signal Coupled to Communication Pair
(in presence of oscilloscope probes)

- PWM pulses response persists ~3us
- Differential amplitude ~140mVpp
- Oscillations are ~125ns



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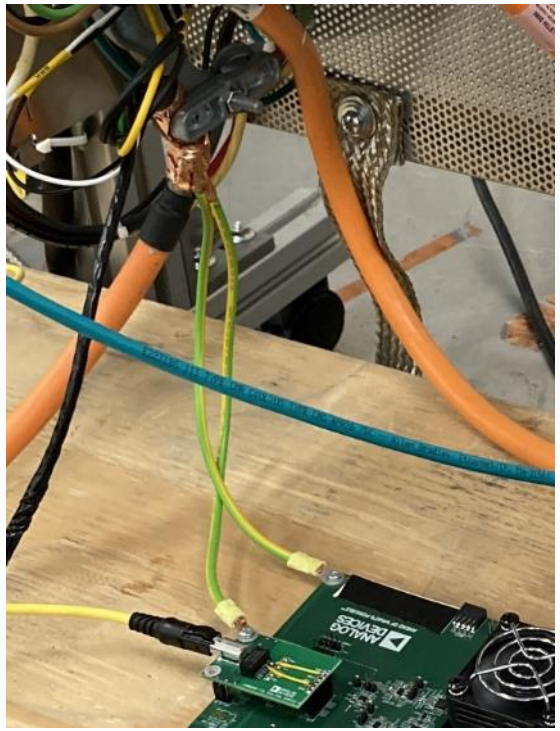
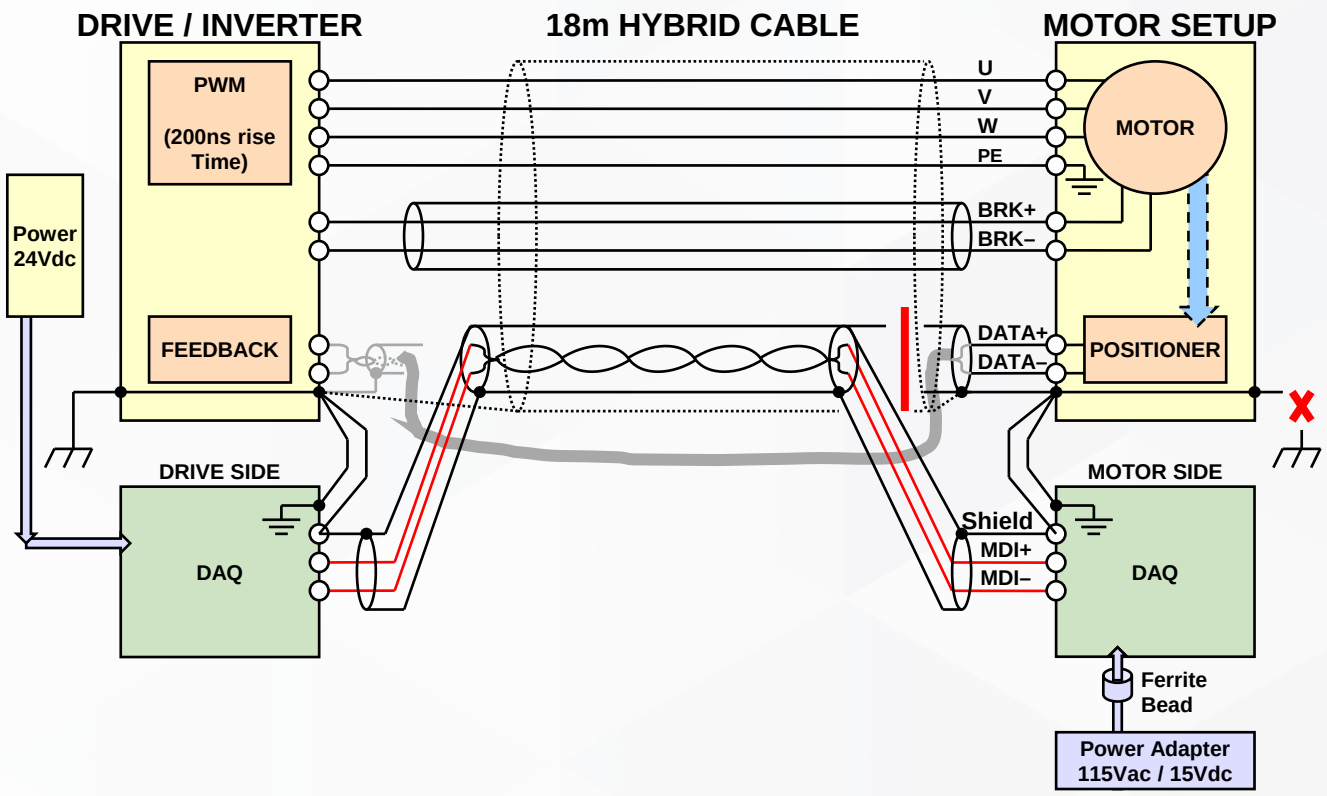
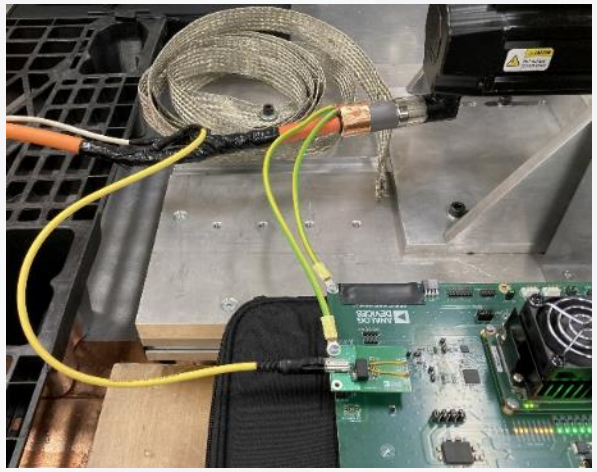
Variant 2
Kinetix 5700
Dual Axis Inverter

Kinetix 5700 Dual Axis Inverter

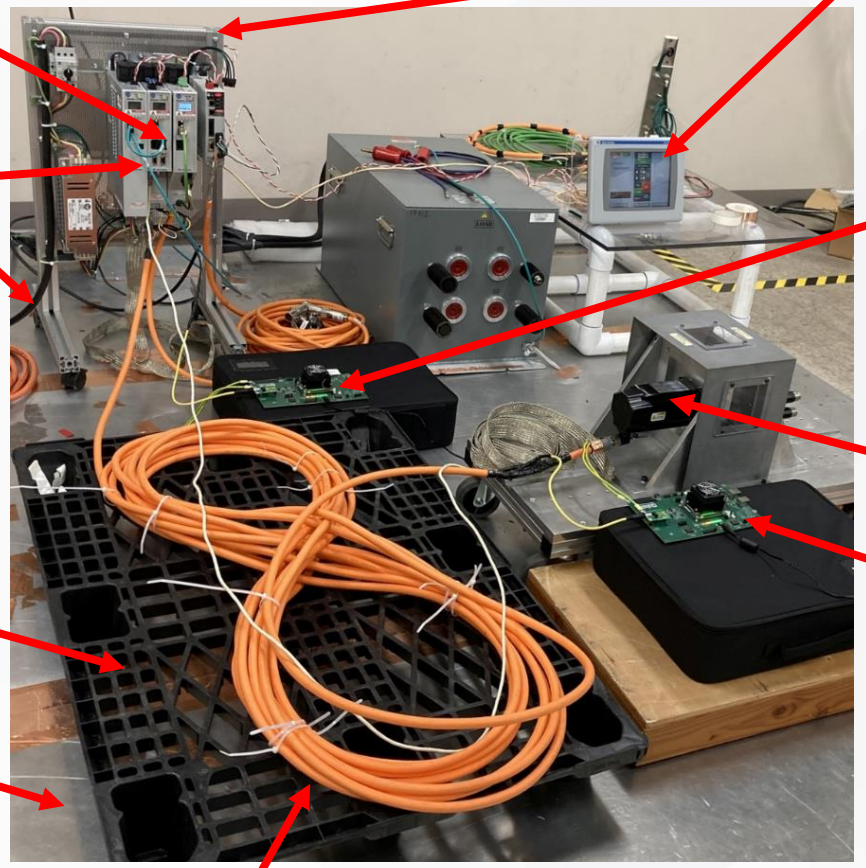






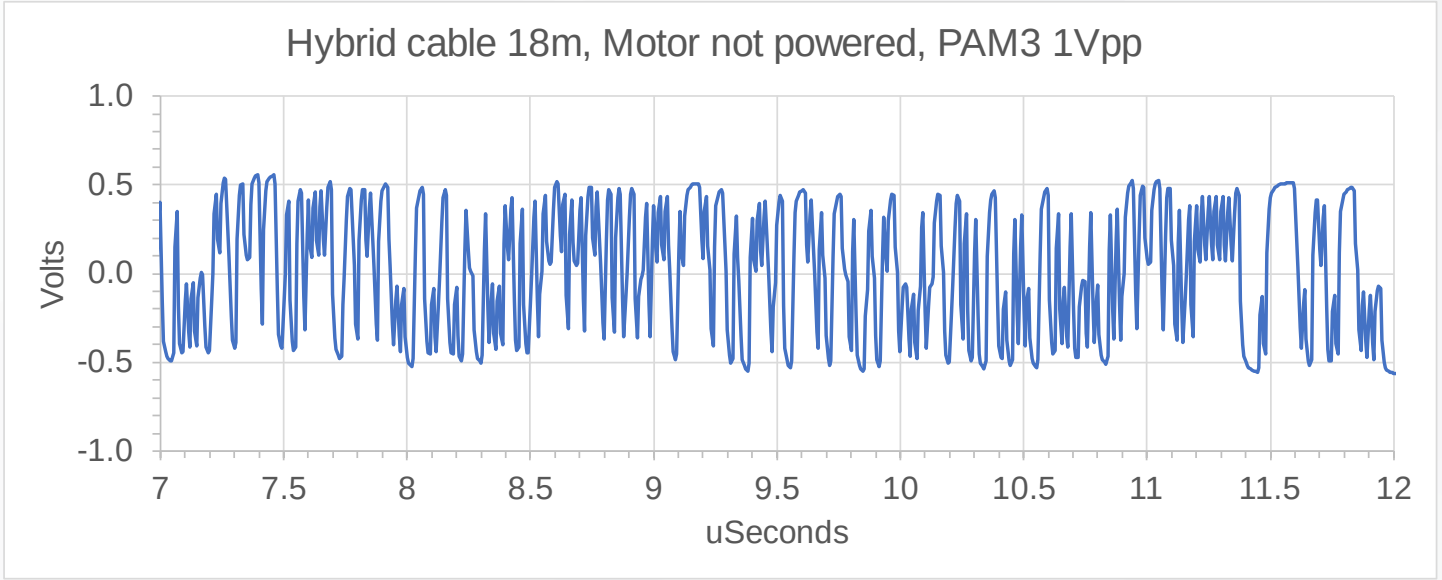
Kinetix 5700 Dual Axis Inverter

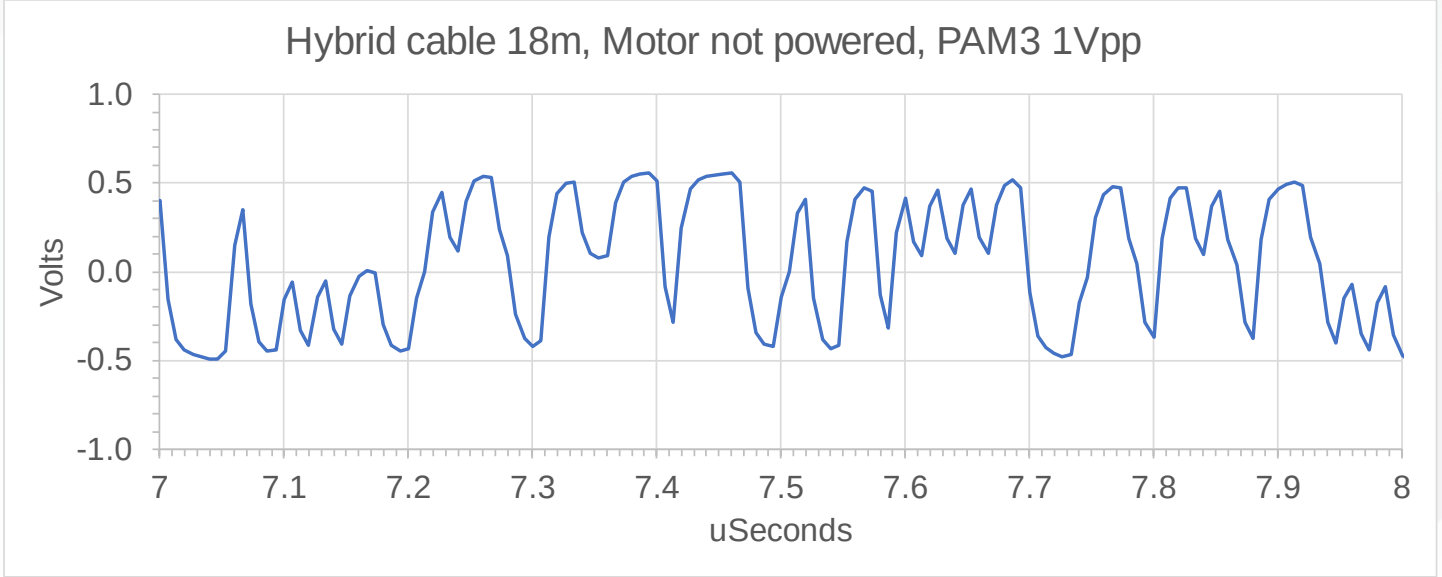
- PWM with 200ns rise time
- 18m Hybrid Cable
- DAQ pair measures coupled PWM interference at each end
- Inverter controls PWM to motor
  - Held in position at zero speed is worst case
- PC uses USB to attach to each DAQ to collect measurement



PAM3 1Vpp Signal

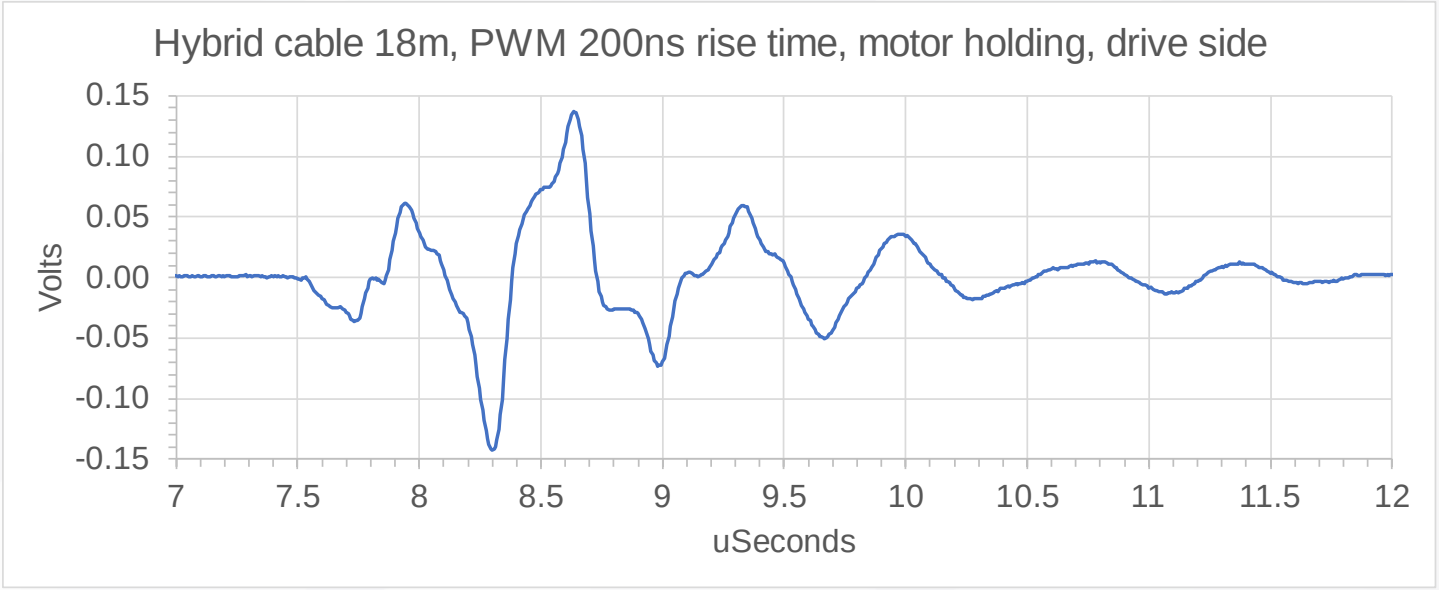
- The Data Acquisition (DAQ) on one side of the cable transmitting PAM3 1Vpp signal
- The DAQ on the other side of cable capturing the signal
- Little attenuation / distortion of the signal on 18m hybrid cable

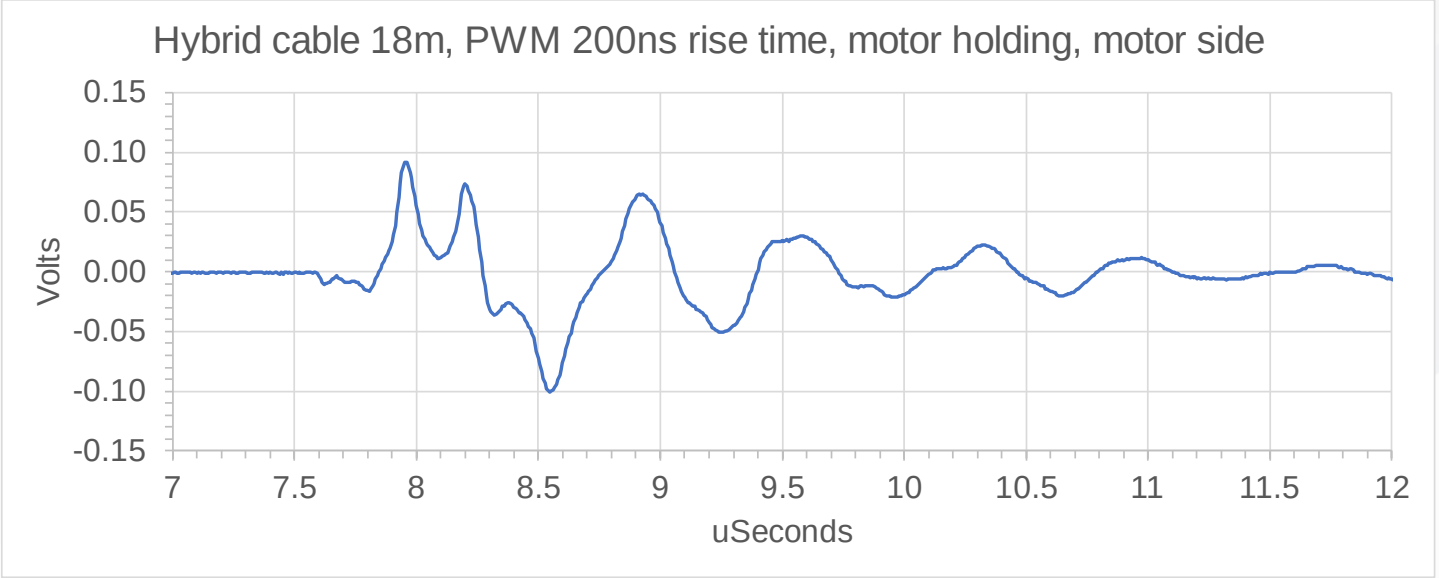




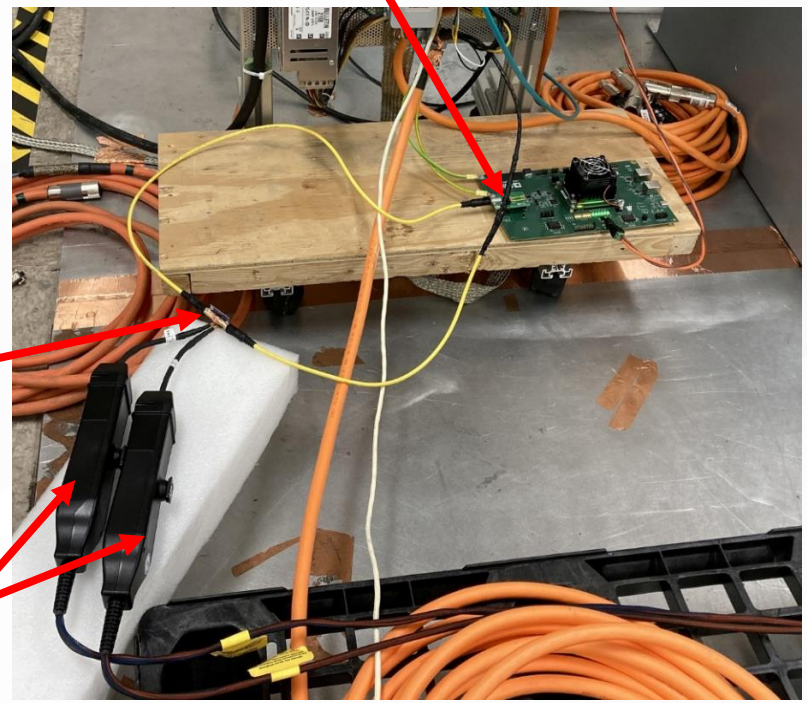
Signal Coupled to Communication Pair

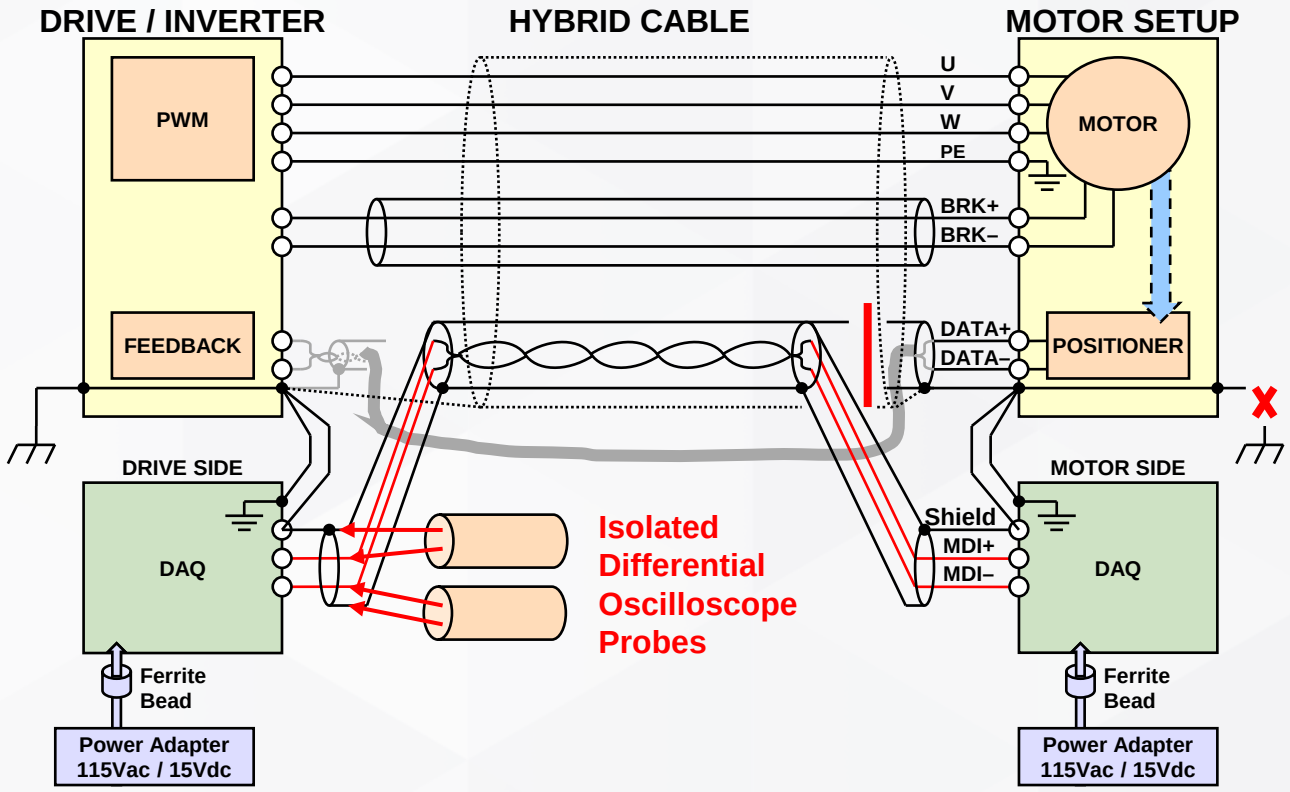
- The Drive outputs 3-phase PWM signal
- The Drive keeps the Motor in “hold” position
  - Motor supplied by PWM signal, but not turning
  - Identified as the worst-case condition
- The DAQ on both sides capturing the signal coupled from the PWM power lines to the communication differential pair





Oscilloscope Captures (Kinetix 5700, 18 m, 200 ns)

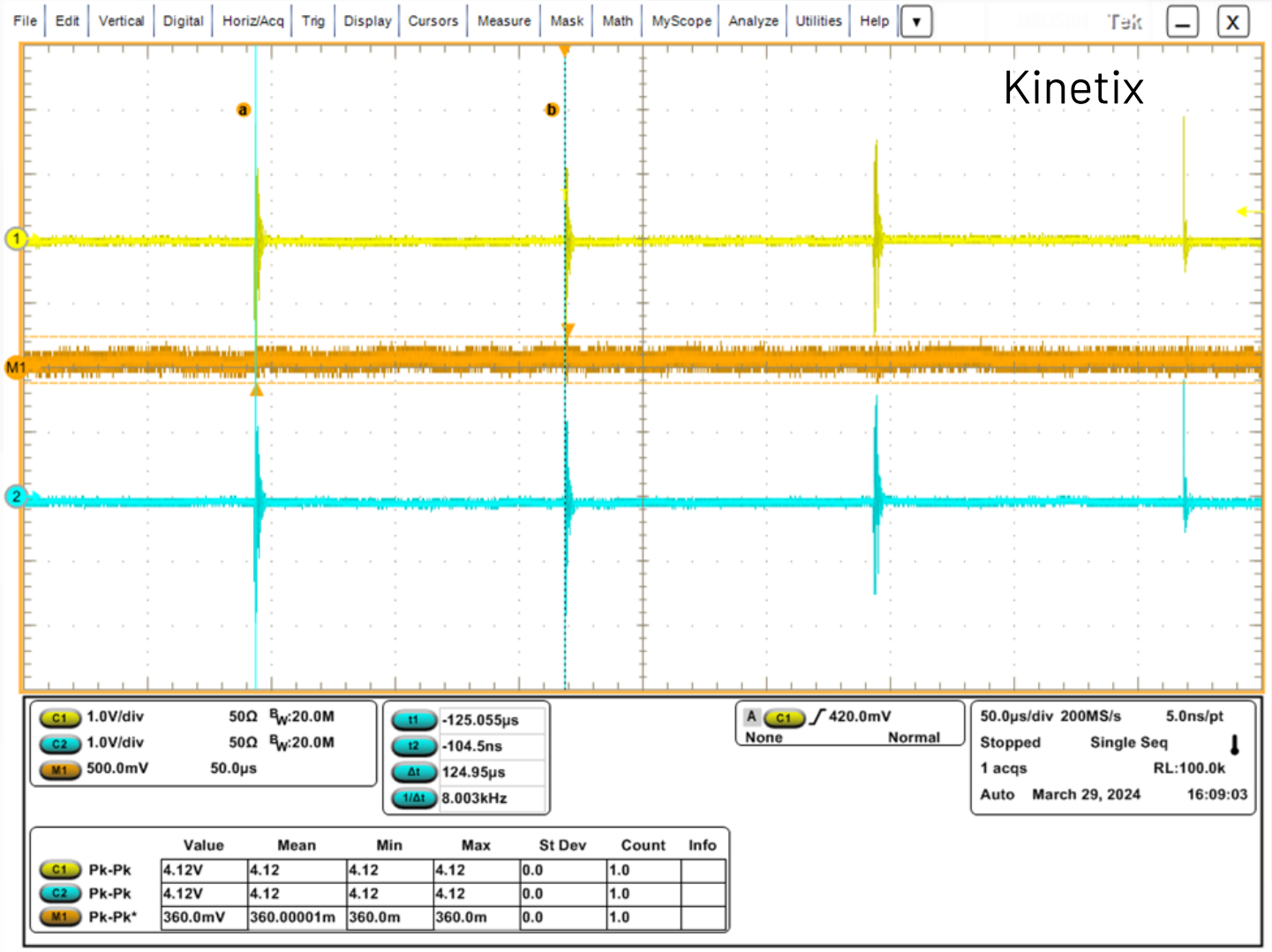




- CH1 and CH2 each measure CM to shield at SPE +/-
- Scope M1 calculates DM
- Allows line-side and PHY-side comparison

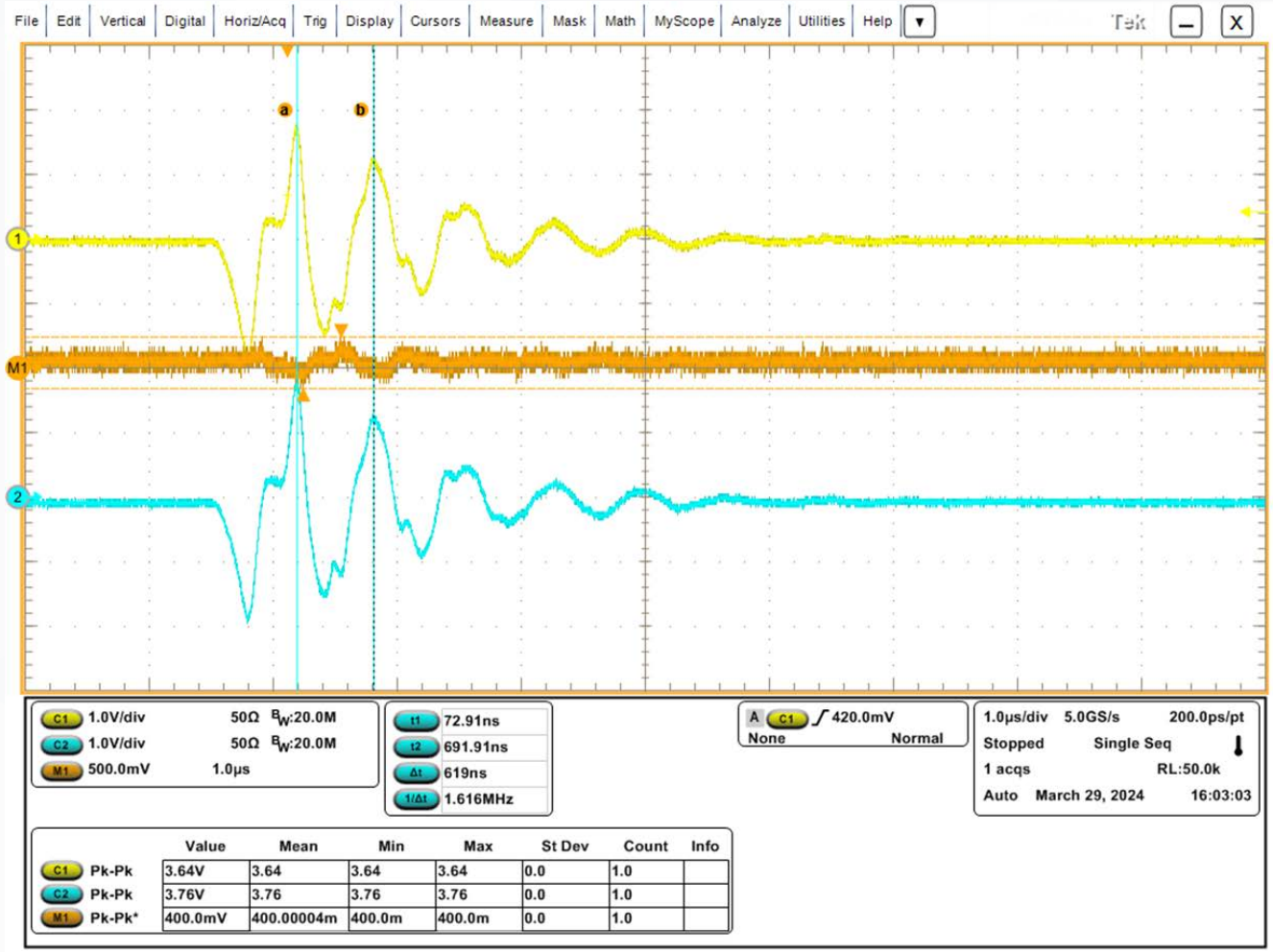
Oscilloscope Capture – PWM

- Wide capture without ADI test pattern to confirm presence of PWM
  - DAQ has limited storage
- PWM transients every 125 us



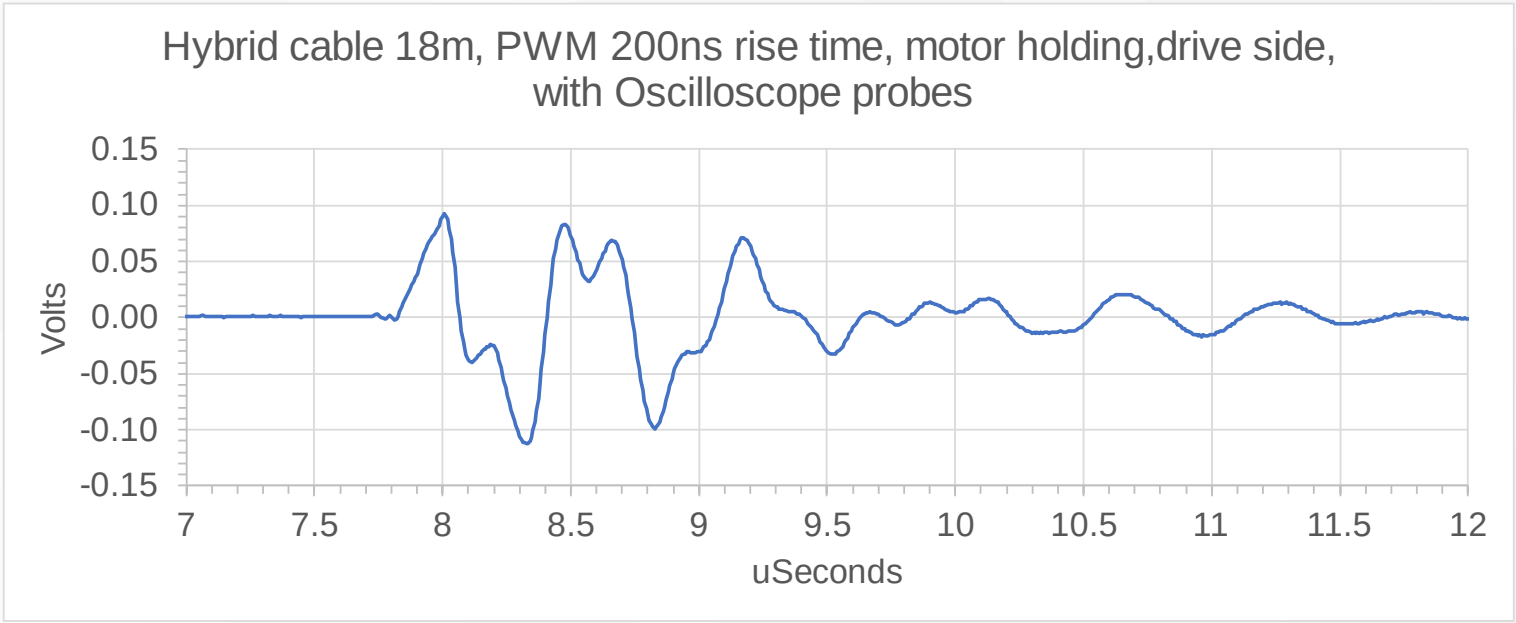
Oscilloscope Capture – PWM

- Kinetix 5700 with 18 m cable
- Short capture to see oscillations in single PWM event
  - Without ADI test pattern
- Oscilloscope filters @ 20 MHz
  - DM measures less than CM by ~9x
  - M1 = 400 mVpp exceeds amplitude at DAQ
- PWM pulses response persists for > 4.5 us
- Oscillations are ~620 ns (1.6 MHz)
  - Relates to cable electrical length
  - Waveform appears to have multiple frequency components
  - The measurement varies by a couple 100 kHz in multiple captures, possibly due to independent addition of frequency components



Signal Coupled to Communication Pair

- PWM pulses response persists > 4 us
  - DAQ has limited buffer
- Differential amplitude ~200 mVpp
- Oscillations are ~600 ns
  - Multiple frequency components



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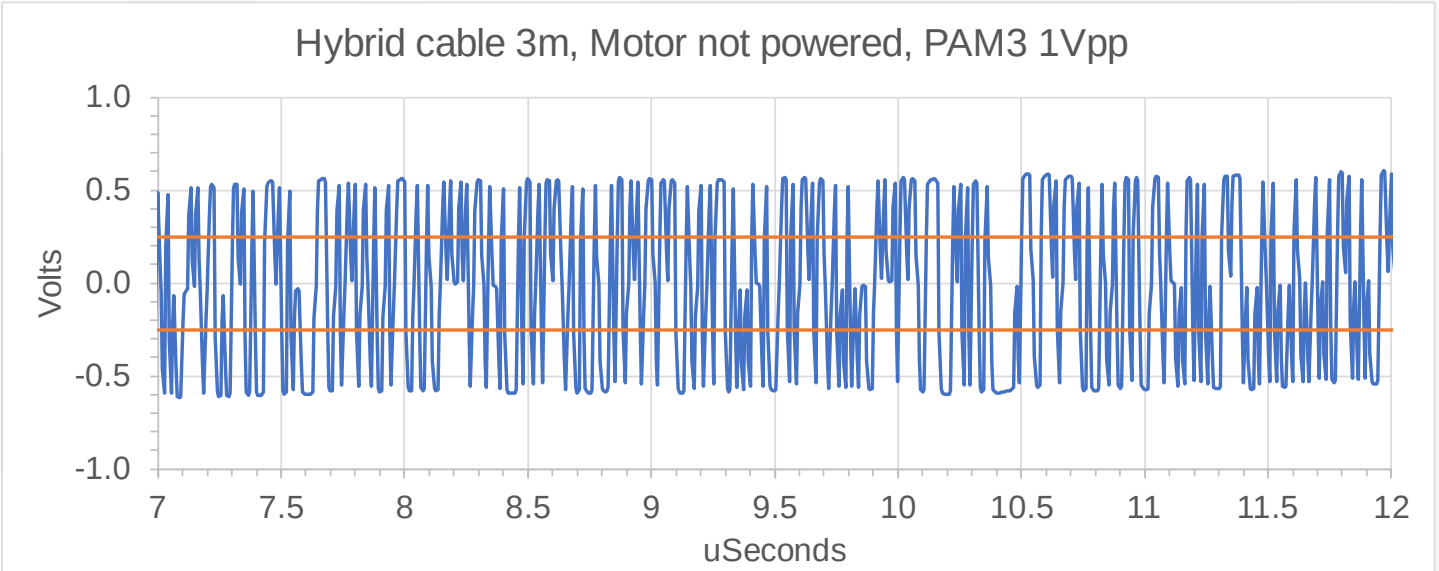
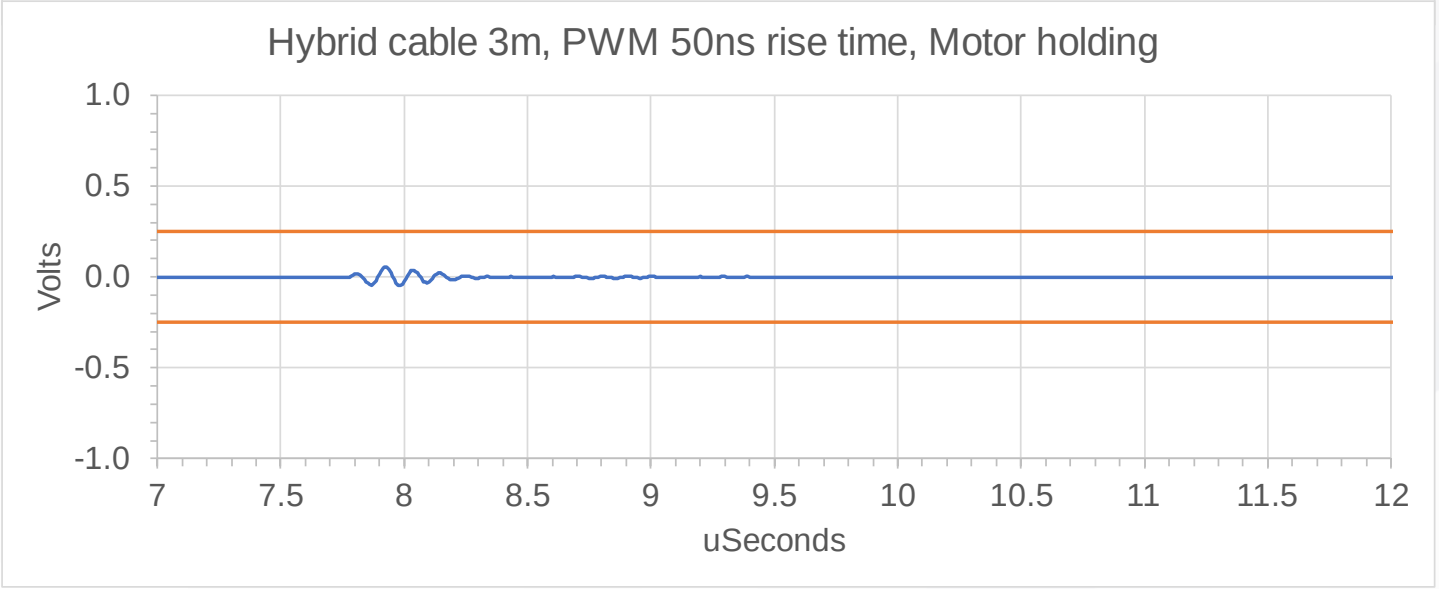
Discussion

Variant 1

ArmorKinetix Distributed Servo Drive (DSD)

- PWM with 50ns rise time
- 3m Hybrid Cable (specified max. 4m)
- PAM3 test signal 1Vpp
  - Passing through 3m cable without visible attenuation
  - Assumed slicer thresholds ±250mV
- Interference signal from motor power PWM coupled to shielded twisted communication pair
  - Motor in holding position
  - Motor not grounded
  - DAQ grounded to cable/connector
- Pulse disturbance approx. ±55mV
  - Amplitude and frequency will depend on cable length, termination, etc…
- Sufficient signal / pulse noise margin
  - Will get only better at higher PAM3 amplitude

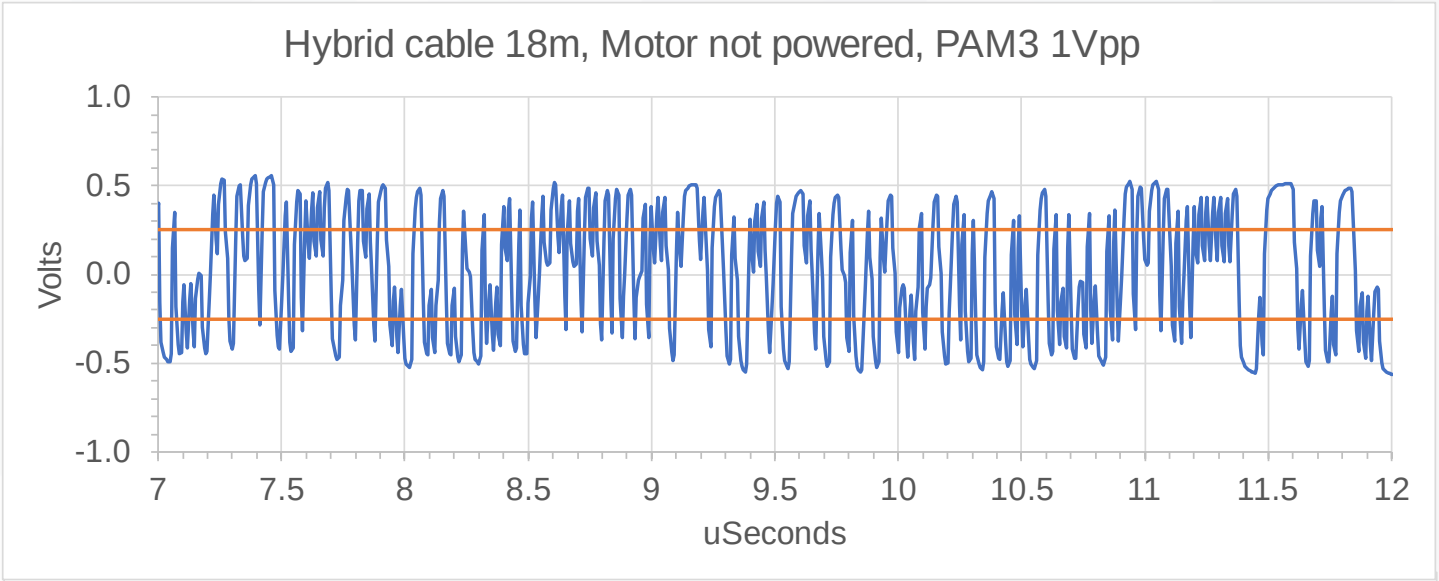




Variant 2

Kinetix 5700 Dual Axis Inverter

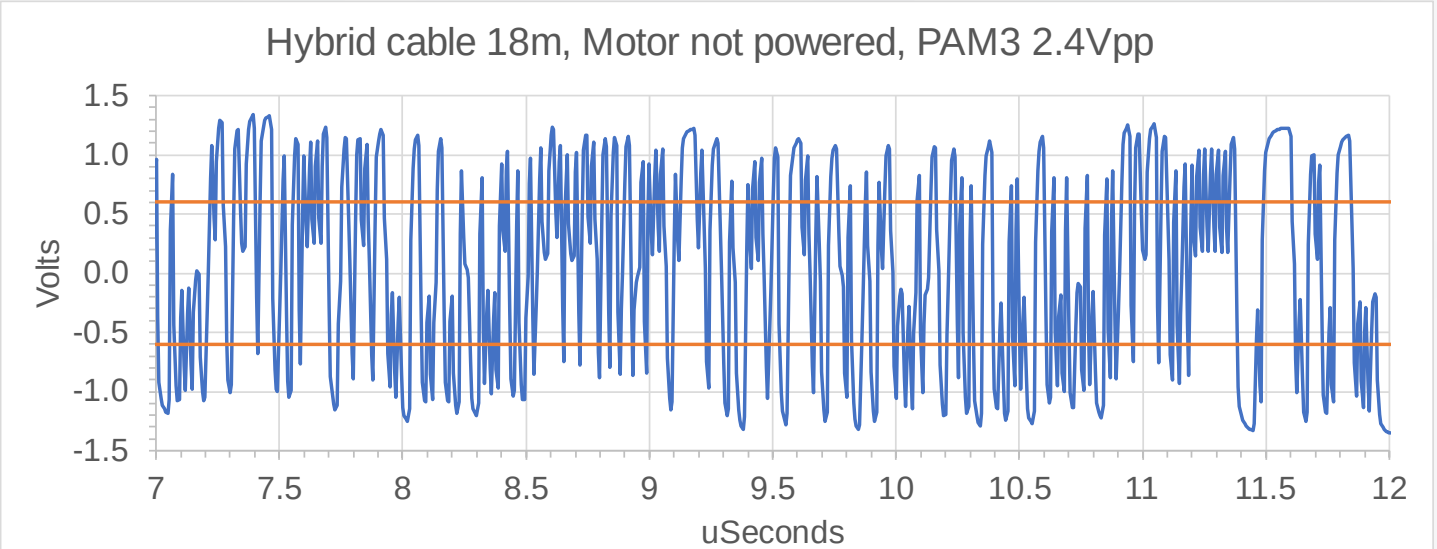
- PWM with 200ns rise time
- 18m Hybrid Cable (specified max. 90m)
- PAM3 test signal 1Vpp
  - Passing through 18m cable with little attenuation
  - Assumed slicer thresholds ±250mV
- Interference signal from motor power PWM coupled to shielded twisted communication pair
  - Motor in holding position
  - Motor not grounded
  - DAQ grounded to cable/connector
- Pulse disturbance approx. ±140mV
  - Amplitude and frequency will depend on cable length, termination, etc…
- Some signal / pulse noise margin
  - Should be better at higher PAM3 amplitude



Variant 2 – but with Higher PAM3 Amplitude

Kinetix 5700 Dual Axis Inverter

- PAM3 signal 2.4Vpp
  - Mathematically scaled from 1Vpp data
    - For visual comparison
    - Validated in a different setup
  - Assumed slicer thresholds => ±600mV
- Pulse disturbance approx. ±140mV
- Better / sufficient signal / pulse noise margin



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Thank you!