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Hybrid Motor Cable Evaluation

Michal Brychta, Analog Devices
Hector Alberti Arroyo, Analog Devices
Jürgen Funkhänel, Sick AG
Marc Lanigra, Sick AG

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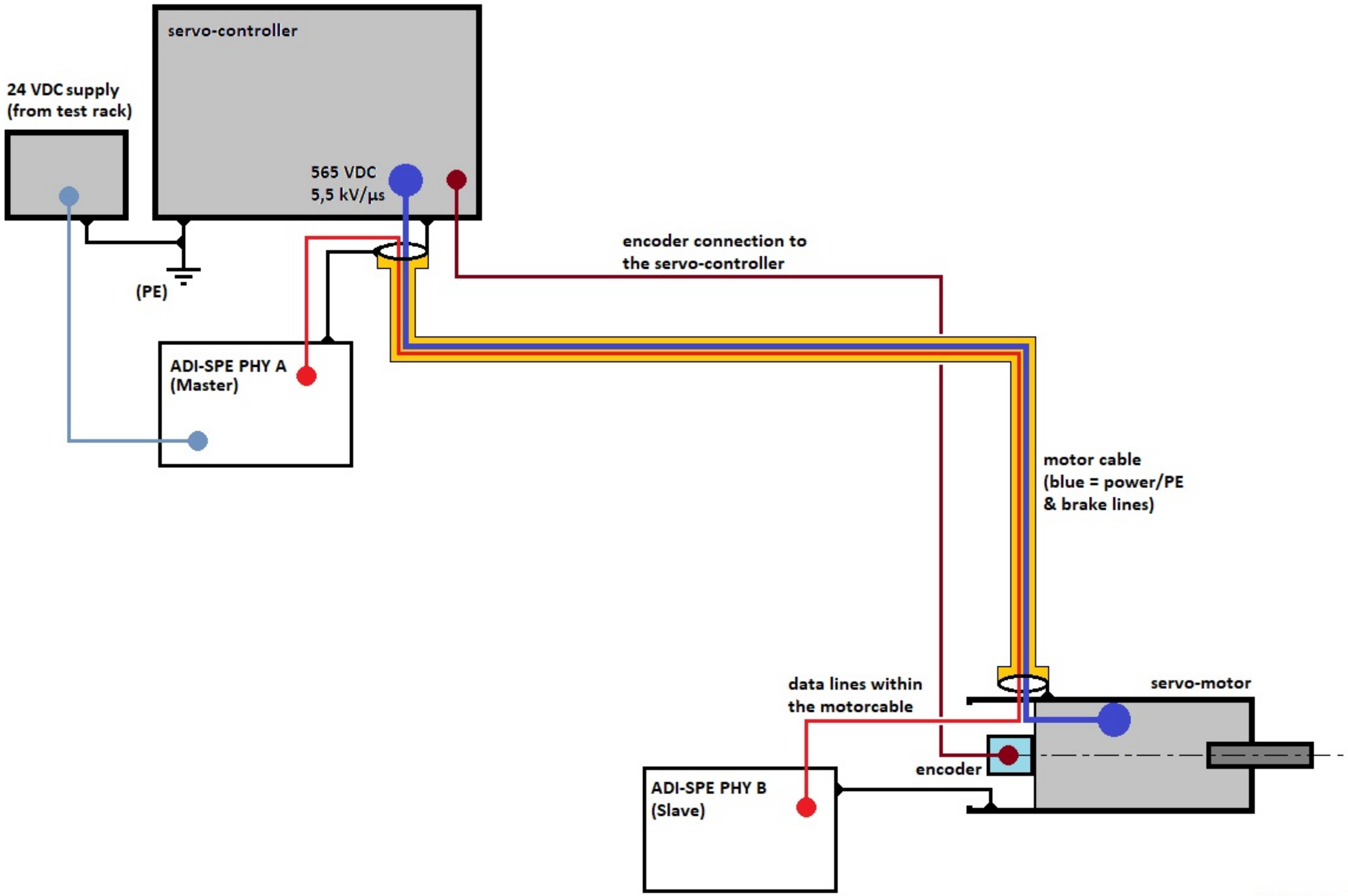
Agenda

- Application
- Cables
  - Structure
  - Measured parameters
- Noise Coupling
  - Motor signal
  - Setup
  - Standard cable performance
  - Advanced cable performance
- 10BASE-T1L
  - Setup
  - Performance
- Summary - Conclusion

Application / Setup



ADI-SPE PHY testing
SICK AppsLab R&D
June 29, 2022

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Hybrid cables

Cables

Hybrid cable

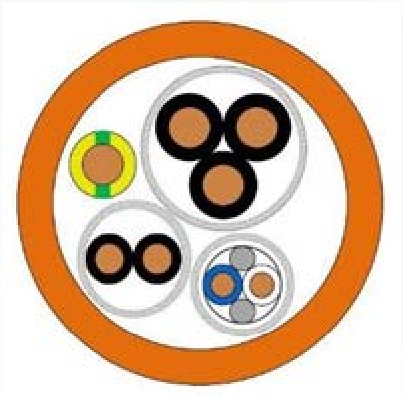
- Cable for connecting of motor setup incl. encoder and positioner with motor drive / controller
- Cable includes power & brake lines together with communication lines within one cable

Standard Hybrid Cable

- Length: 5 m & 100 m
- Configuration:
  [4G1,5+(2x0,75)+(AWG22)]

Advanced Hybrid Cable

- Length: 100 m
- Configuration:
  G2,5+(3xG2,5)+(2x1)+(2x22AWG)



Cable Insertion Loss

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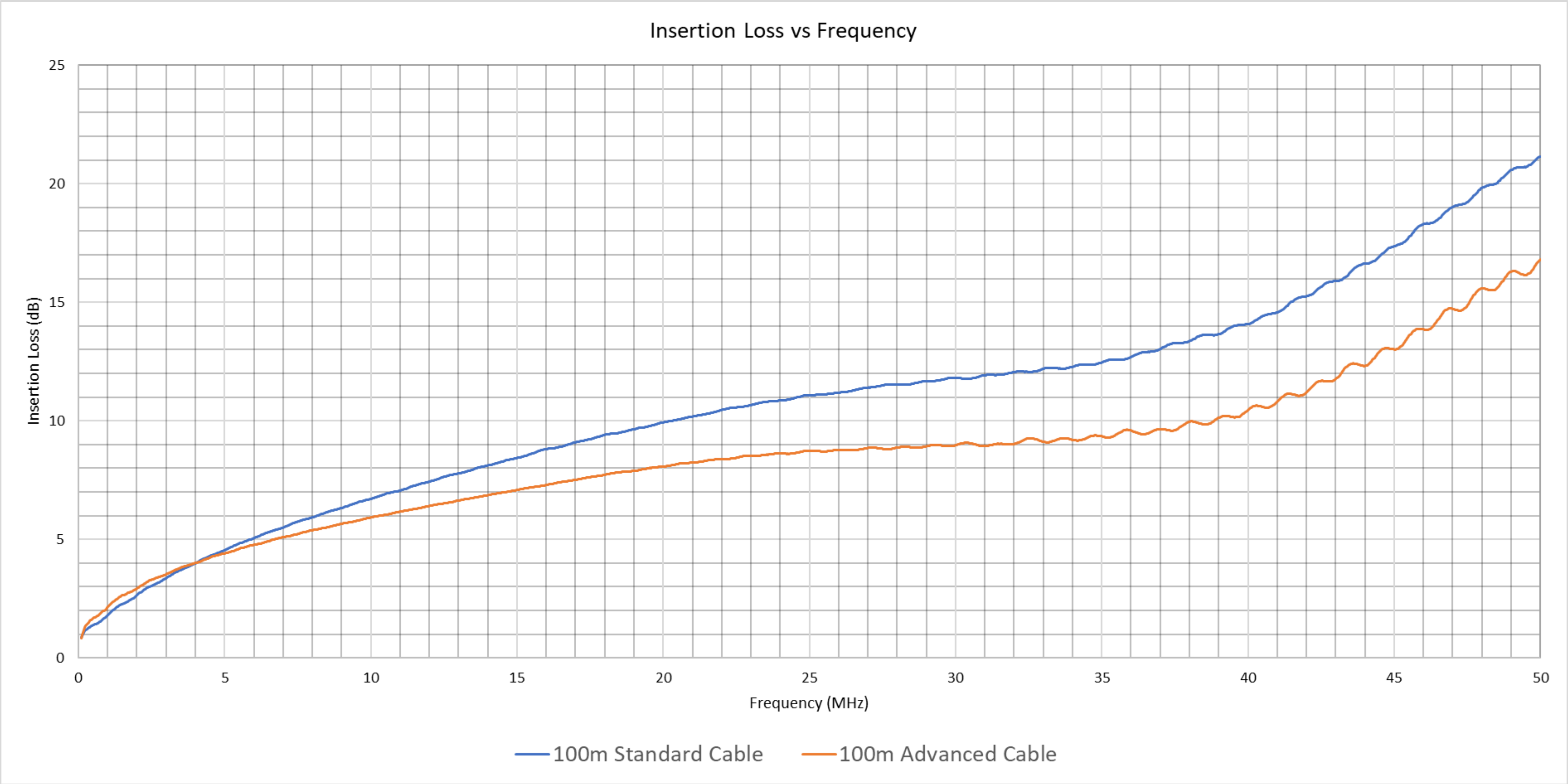
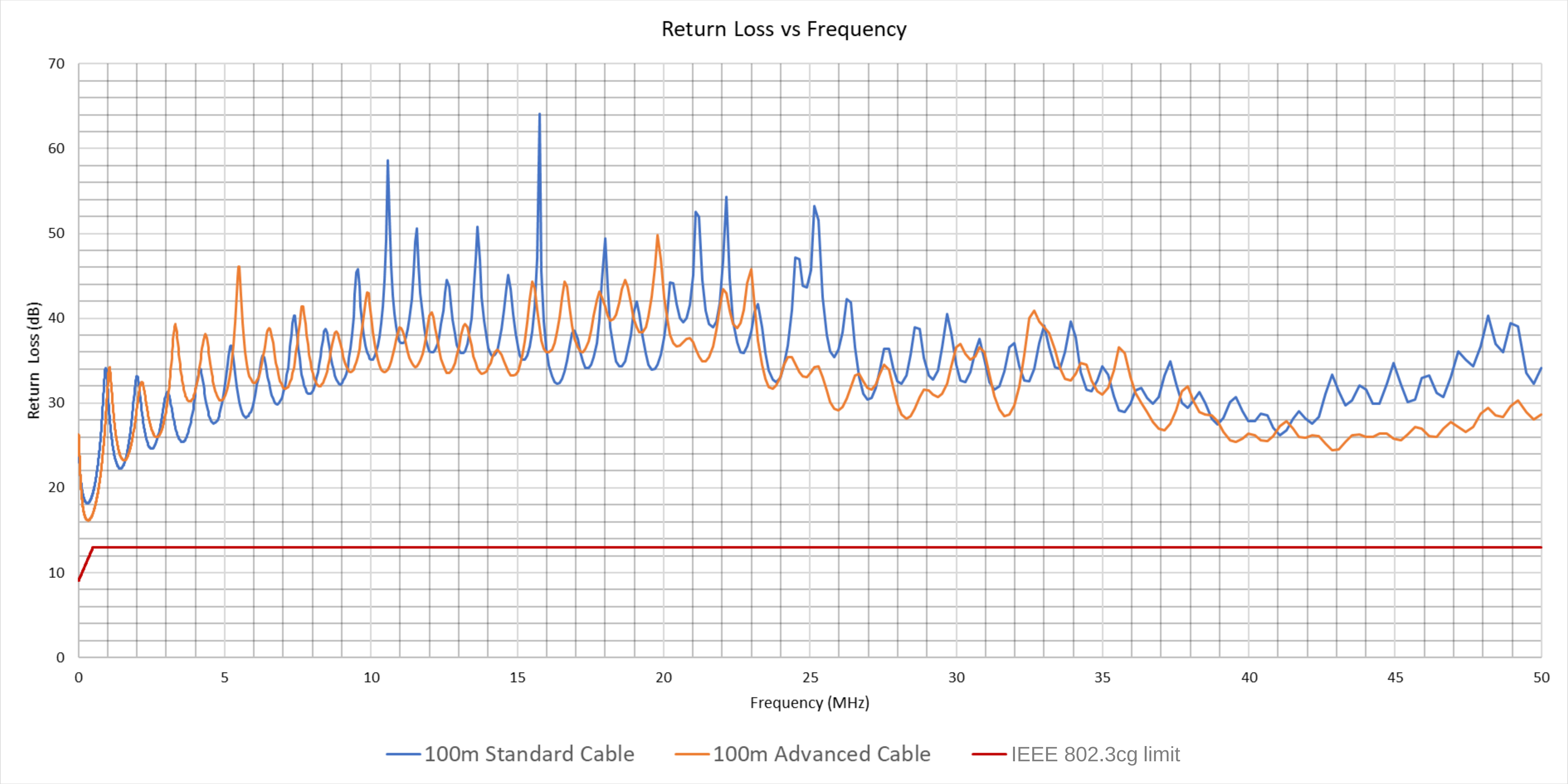
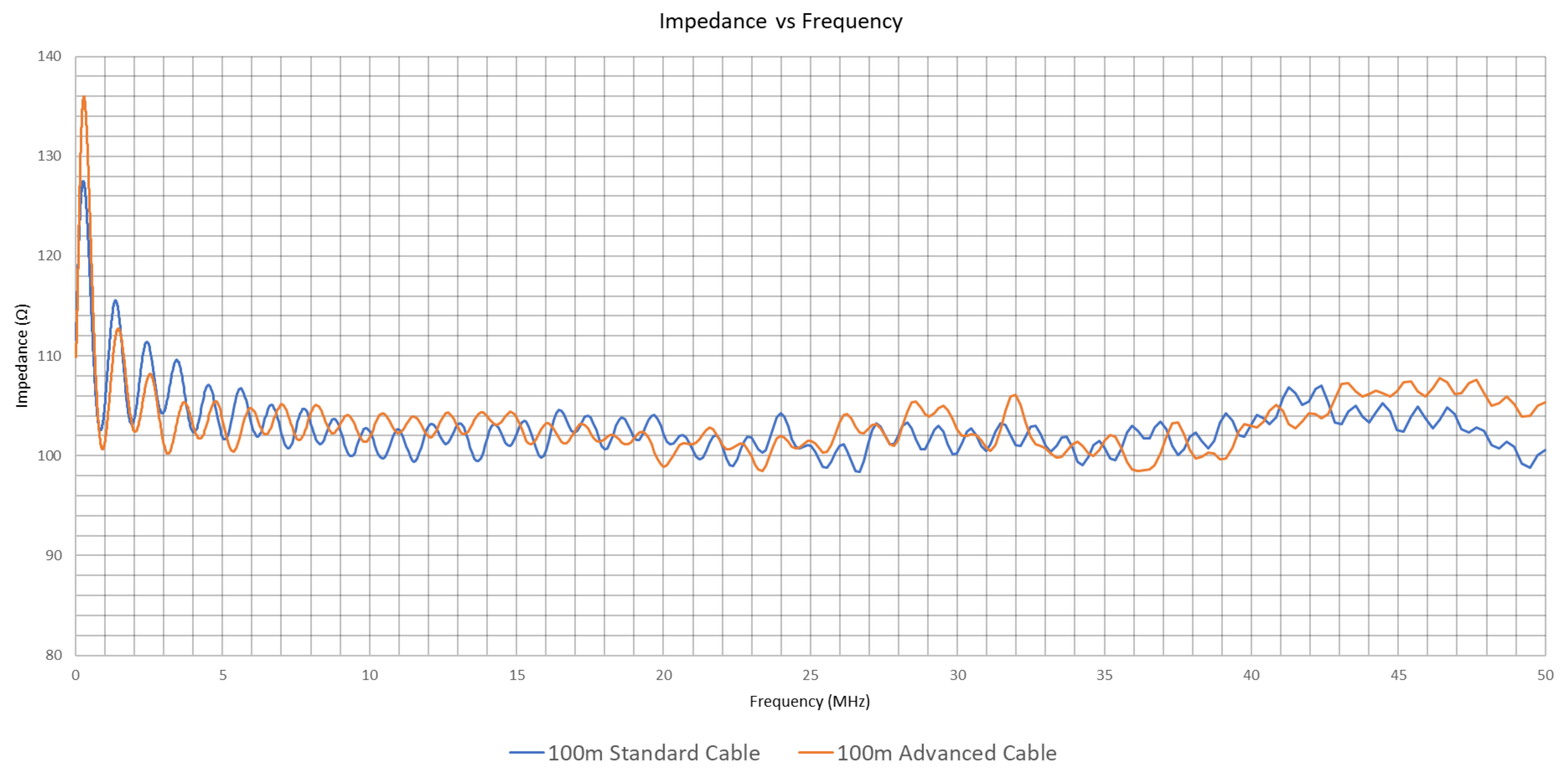


Cable Return Loss



Cable Impedance



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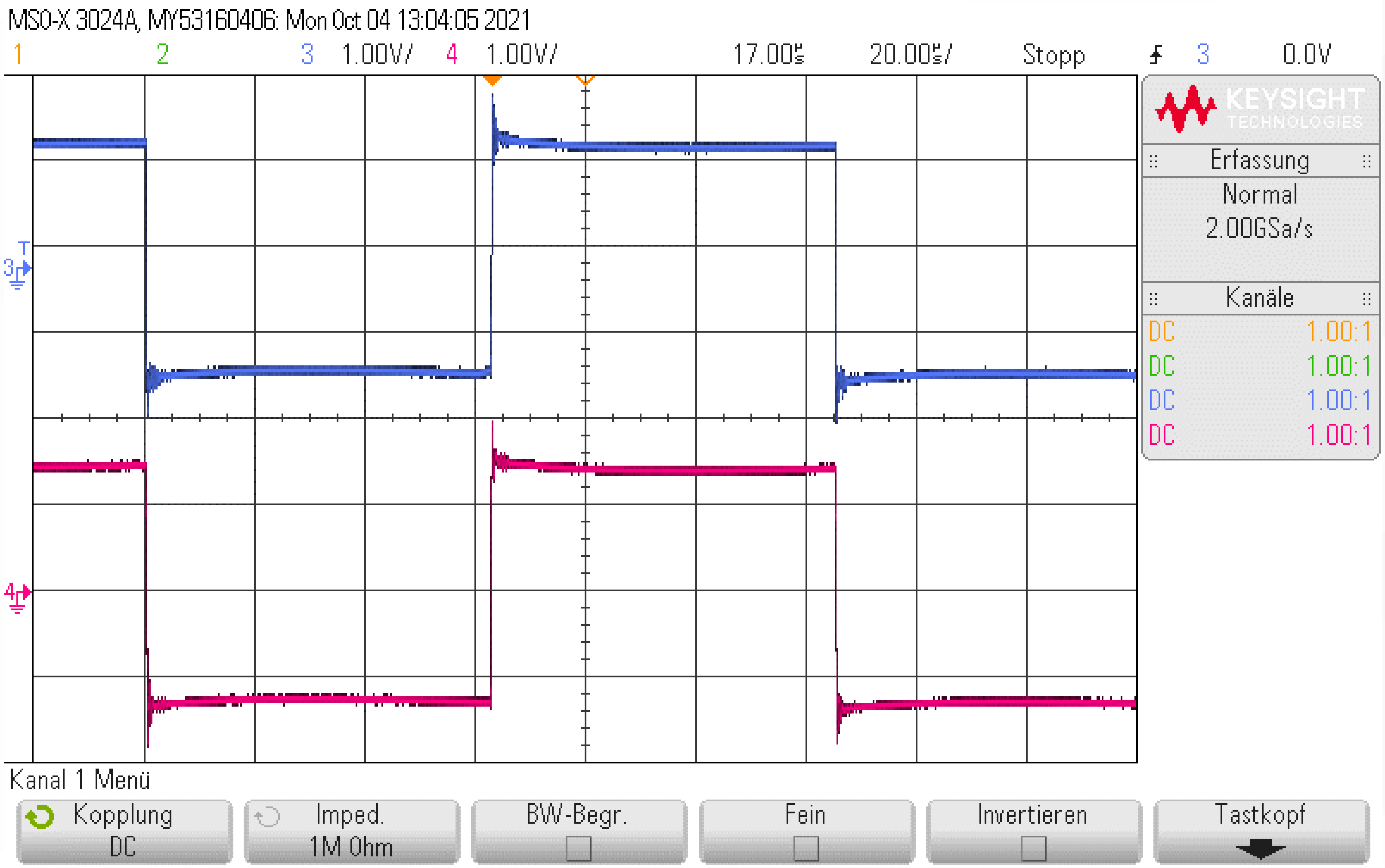
Noise coupling
Standard hybrid cable

Motor Power Signals

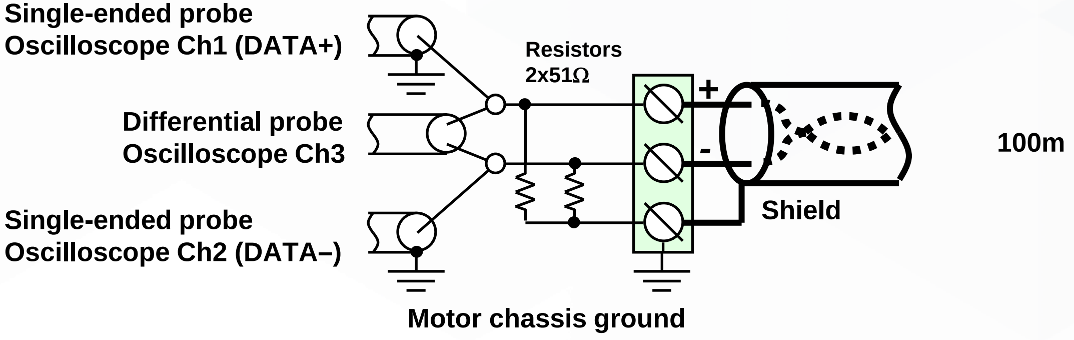


- 2 out of 3 motor power signals
- Captured with a with high voltage 200:1 oscilloscope probes
- 16kHz / 62.5us period 3-phase PWM
- Amplitude approx. 550V
- Slew rate approx. 5.5kV/us
  - Full level reached within approx. 100ns
  - New/future applications up to 10kV/us
- Motor powered, idle, not turning
  - The phases switch nearly at the same time, a few ns in-between only.

Setup for Noise Measurement

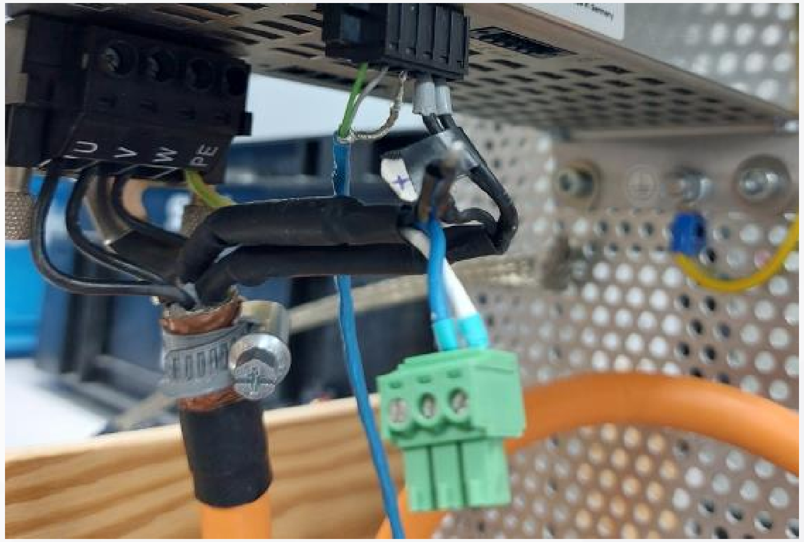
Motor Side Connection

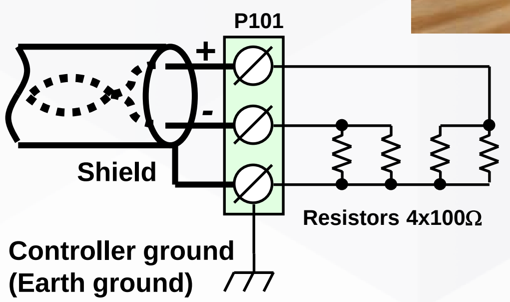
- Terminated 102 ohm differential
- 25 ohm common mode to motor chassis
- Oscilloscope ground referred to motor chassis
- Oscilloscope up to 5 GSamples/s
- Single-ended probe BW 500MHz, 3.9pF/10MΩ
- Differential active probe, BW 1.5GHz, 1pF/200kΩ



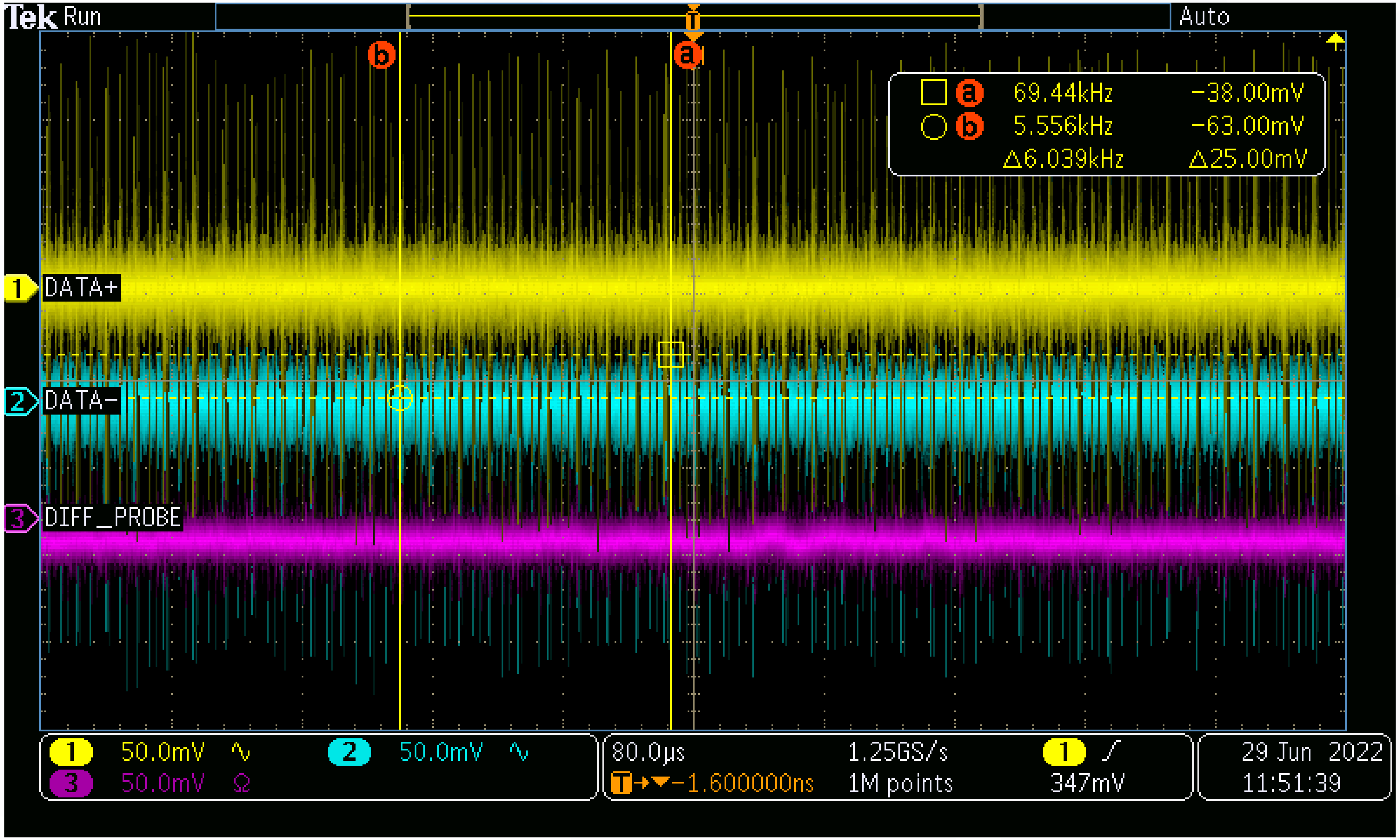
Drive Side Connection

- Terminated 100 ohm differential
- 25 ohm common mode to ground



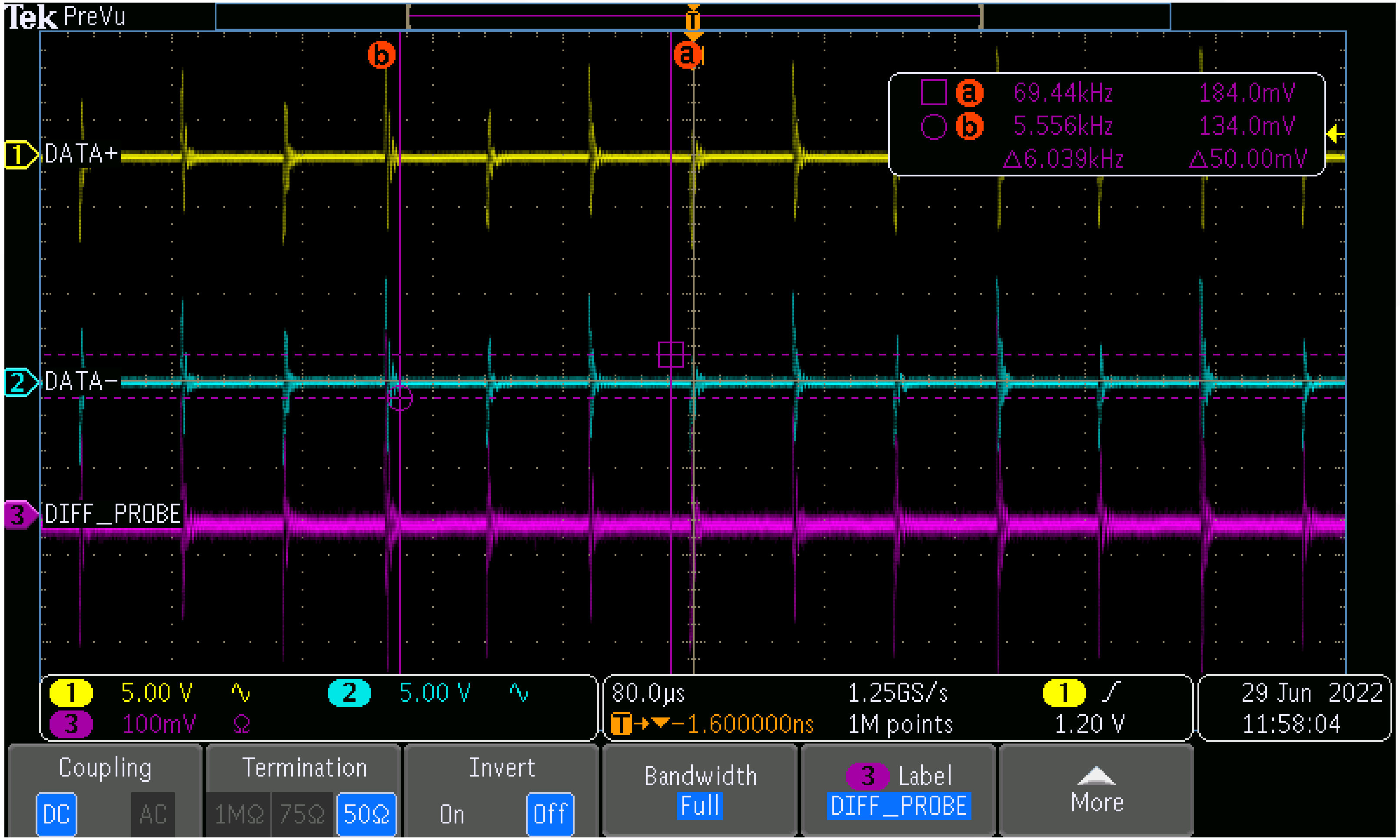


Cable A “Standard Hybrid Cable”
Motor power off, setup / background noise



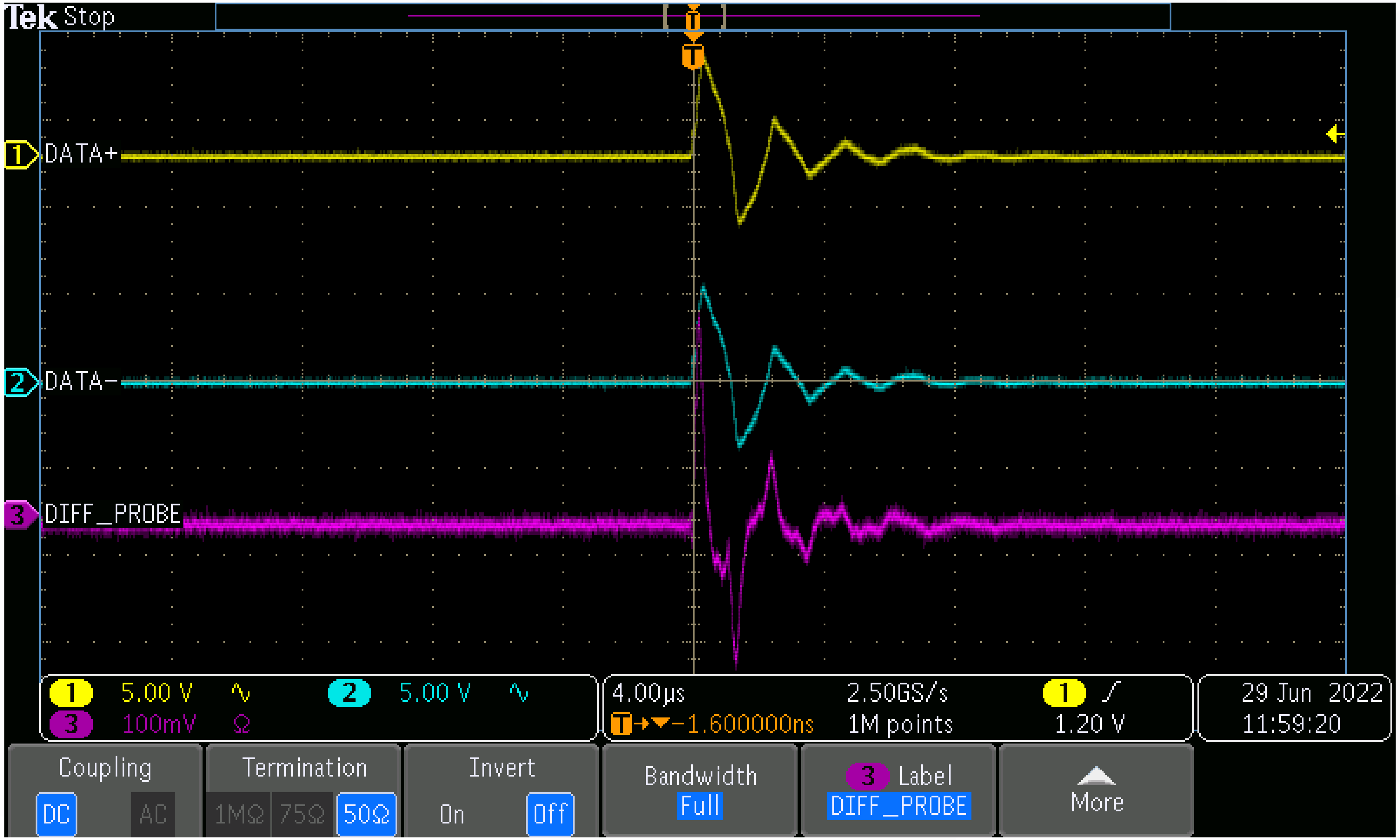
- Ch1 (yellow) and Ch2 (blue) single ended, common mode, from communication signals to ground
- Common mode noise ~200mVpp
- Ch3 (purple) differential probe between communication signals
- Differential noise ~50mVpp

Cable A "Standard Hybrid Cable" Motor powered, idle, not turning



- Bursts of noise by the edges of PWM motor power signals
- Ch1 (yellow) and Ch2 (blue) single ended, common mode, from communication signals to ground
- Common mode noise ~10Vpp
- Ch3 (purple) differential probe between communication signals
- Differential noise ~400mVpp

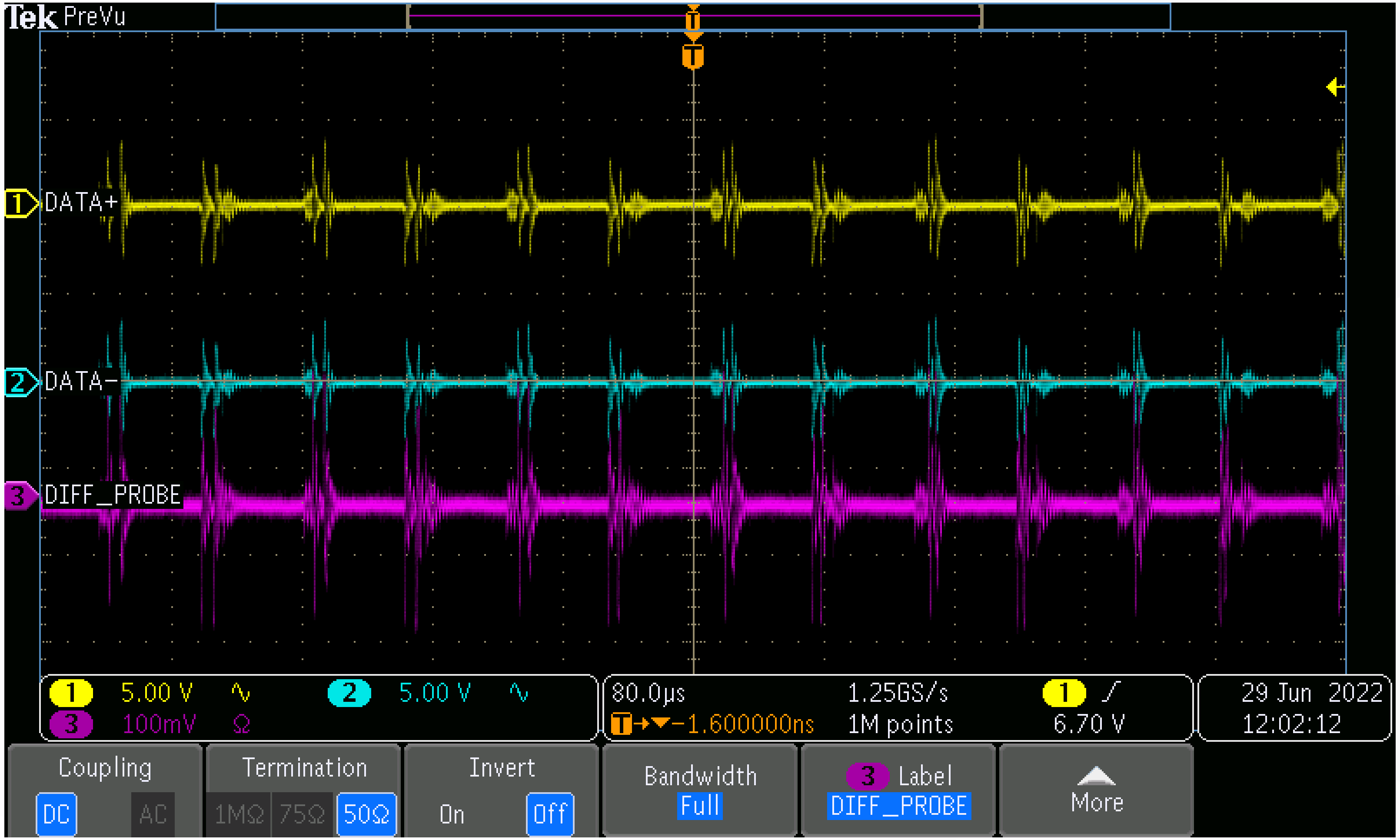
Cable A "Standard Hybrid Cable"
Motor powered, idle, not turning - detail



- Time zoomed to detail around an edge of the PWM motor power signals
- Ch1 (yellow) and Ch2 (blue) single ended, common mode, from communication signals to ground
- Ch3 (purple) differential probe between communication signals

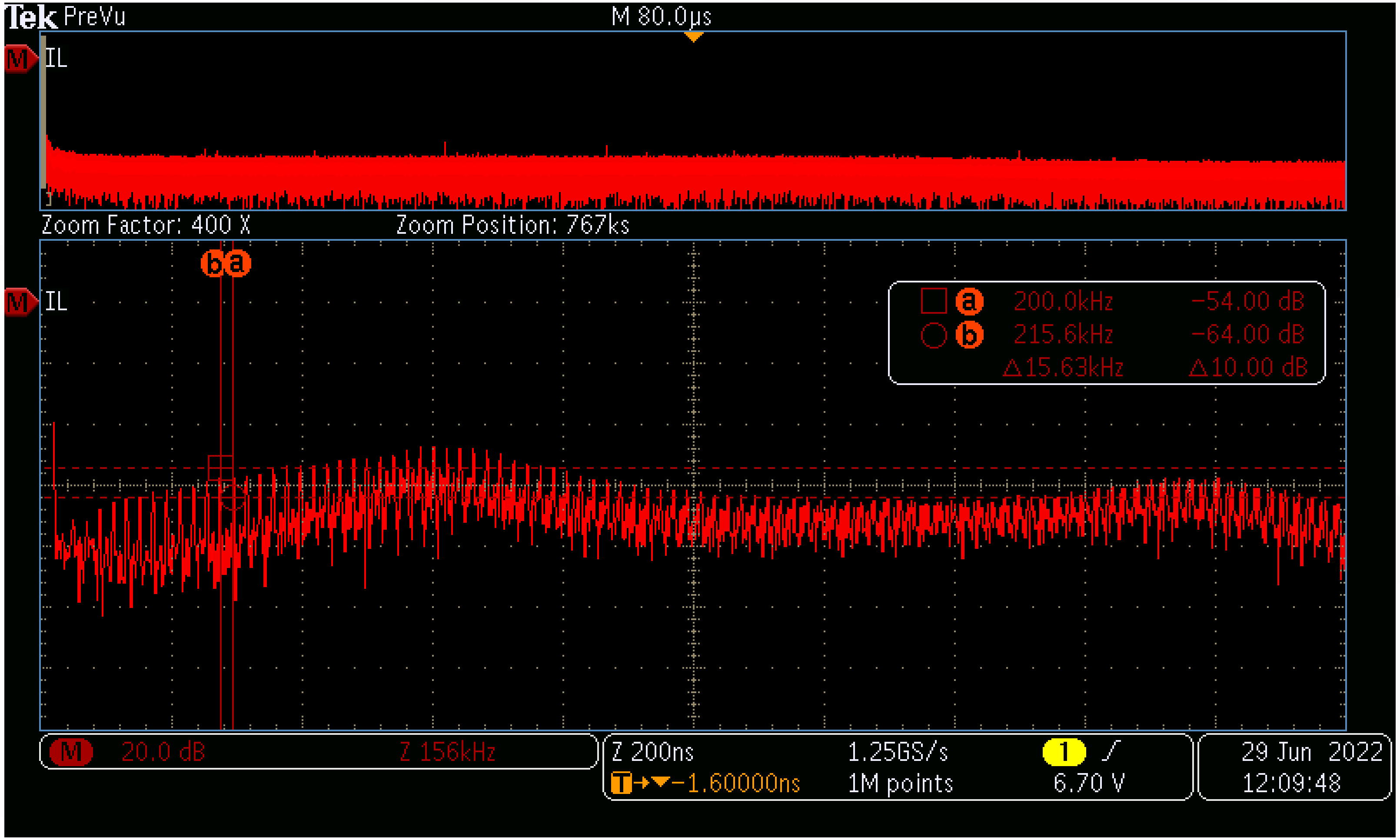
Cable A "Standard Hybrid Cable" Motor running, changing direction

(Clockwise – Anticlockwise – Clockwise ...)



- Bursts of noise by the edges of PWM motor power signals
  - Edges of the PWM 3-phases not aligned as the motor is controlled to move
- Ch1 (yellow) and Ch2 (blue) single ended, common mode, from communication signals to ground
- Common mode noise ~10Vpp
- Ch3 (purple) differential probe between communication signals
- Differential noise ~400mVpp

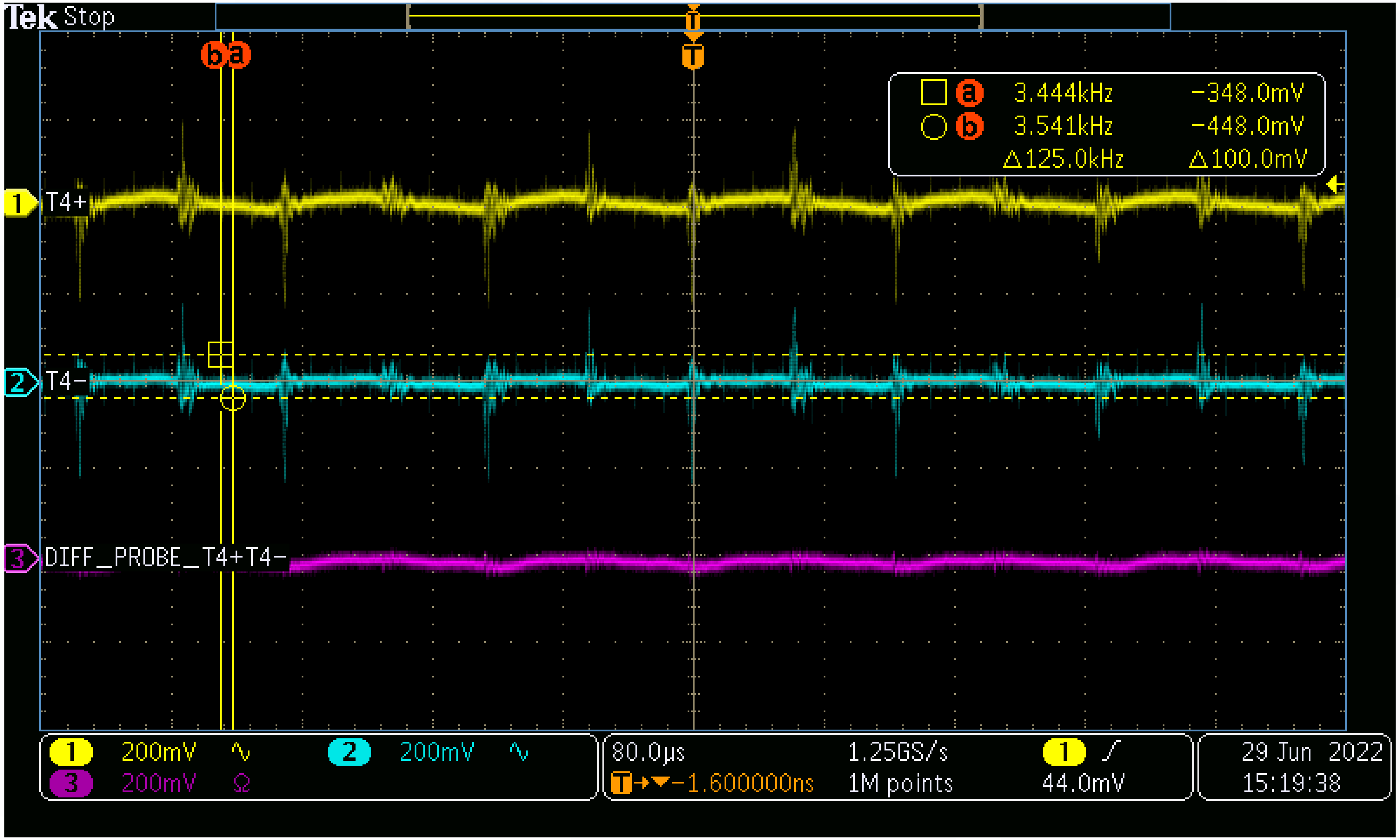
Cable A "Standard Hybrid Cable"
Motor running, changing direction – FFT



- Differential probe between communication signals
- FFT, Hanning, logrms
- Freq zoom shows harmonics of the 16kHz PWM motor power signals

Noise coupling
Advanced hybrid cable

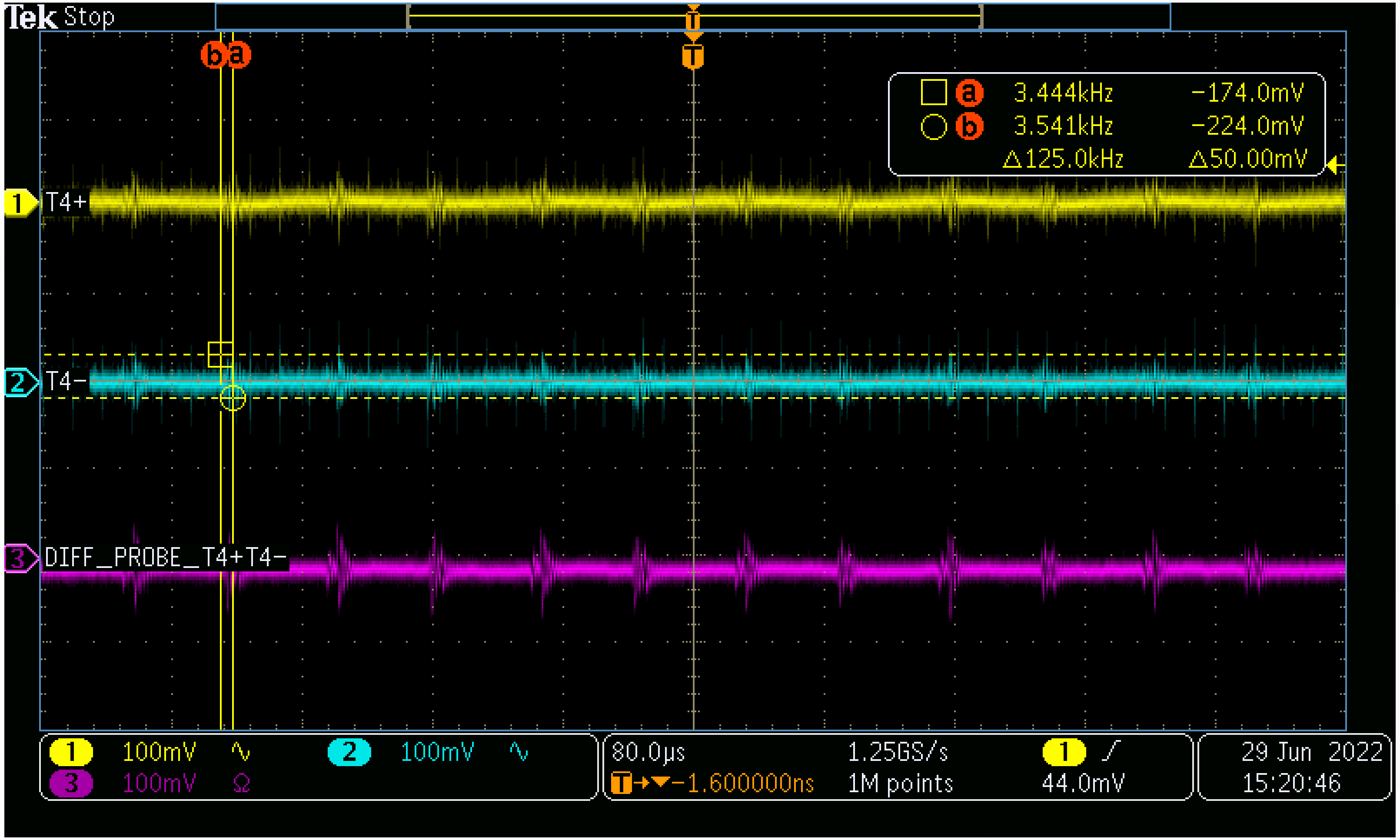
Cable B “Advanced Hybrid Cable”
Motor powered, idle, not turning



- Bursts of noise by the edges of PWM motor power signals
- Ch1 (yellow) and Ch2 (blue) single ended, common mode, from communication signals to ground
- Common mode noise ~400mVpp
- Ch3 (purple) differential probe between communication signals
- Differential noise ~50mVpp

Cable B “Advanced Hybrid Cable” Motor running, changing direction

(Clockwise – Anticlockwise – Clockwise ...)



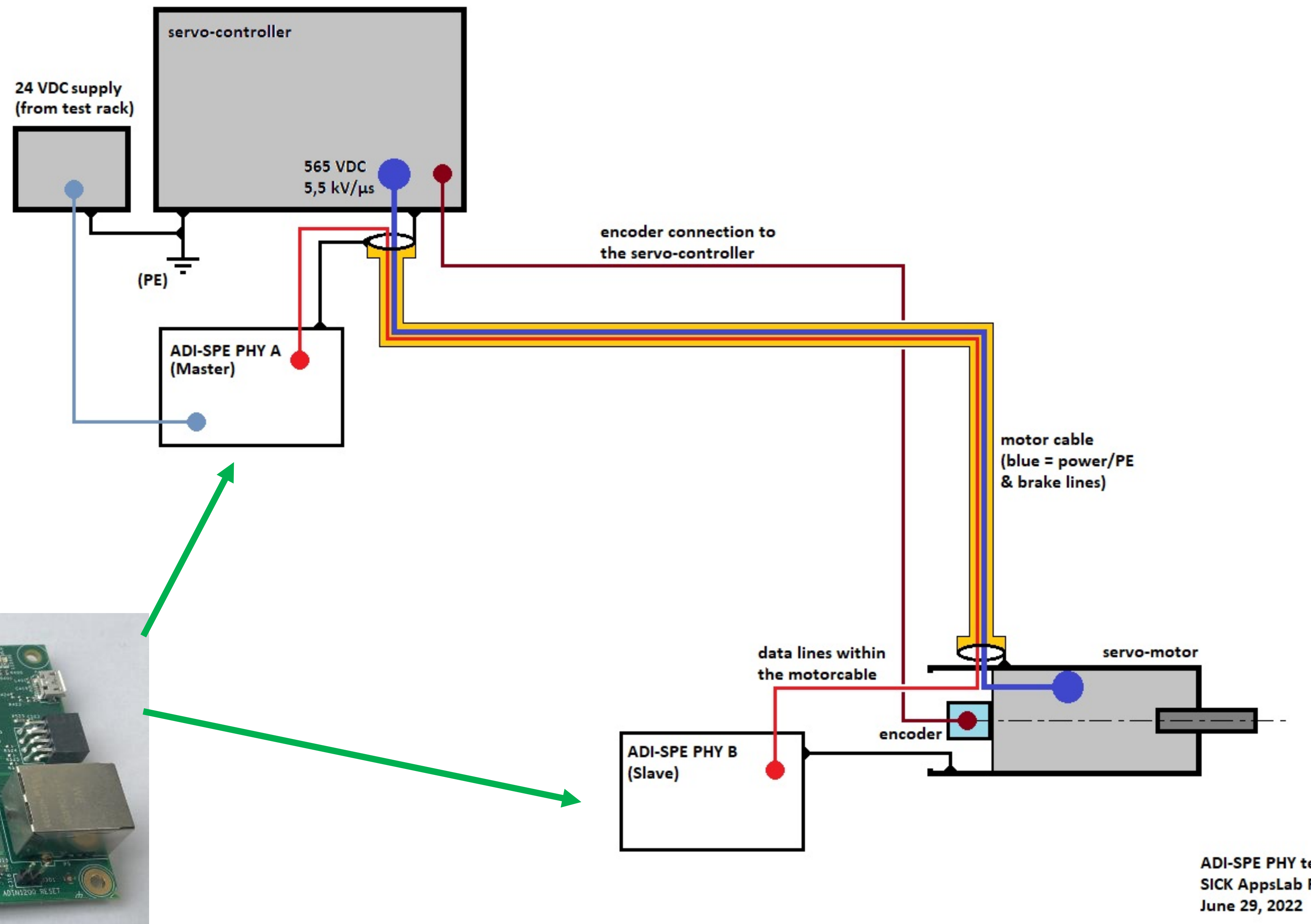
- Bursts of noise by the edges of PWM motor power signals
  - Edges of the PWM 3-pahses not aligned as the motor is controlled to move
- Ch1 (yellow) and Ch2 (blue) single ended, common mode, from communication signals to ground
- Common mode noise <100mVpp
- Ch3 (purple) differential probe between communication signals
- Differential noise ~50mVpp

10BASE-T1L performance

Note that we evaluated 10BASE-T1L

NOT 100BASE-Txx !!!

Setup for 10BASE-T1L Performance



EVAL-ADIN1100EBZ

10BASE-T1L / Cable / System Connections

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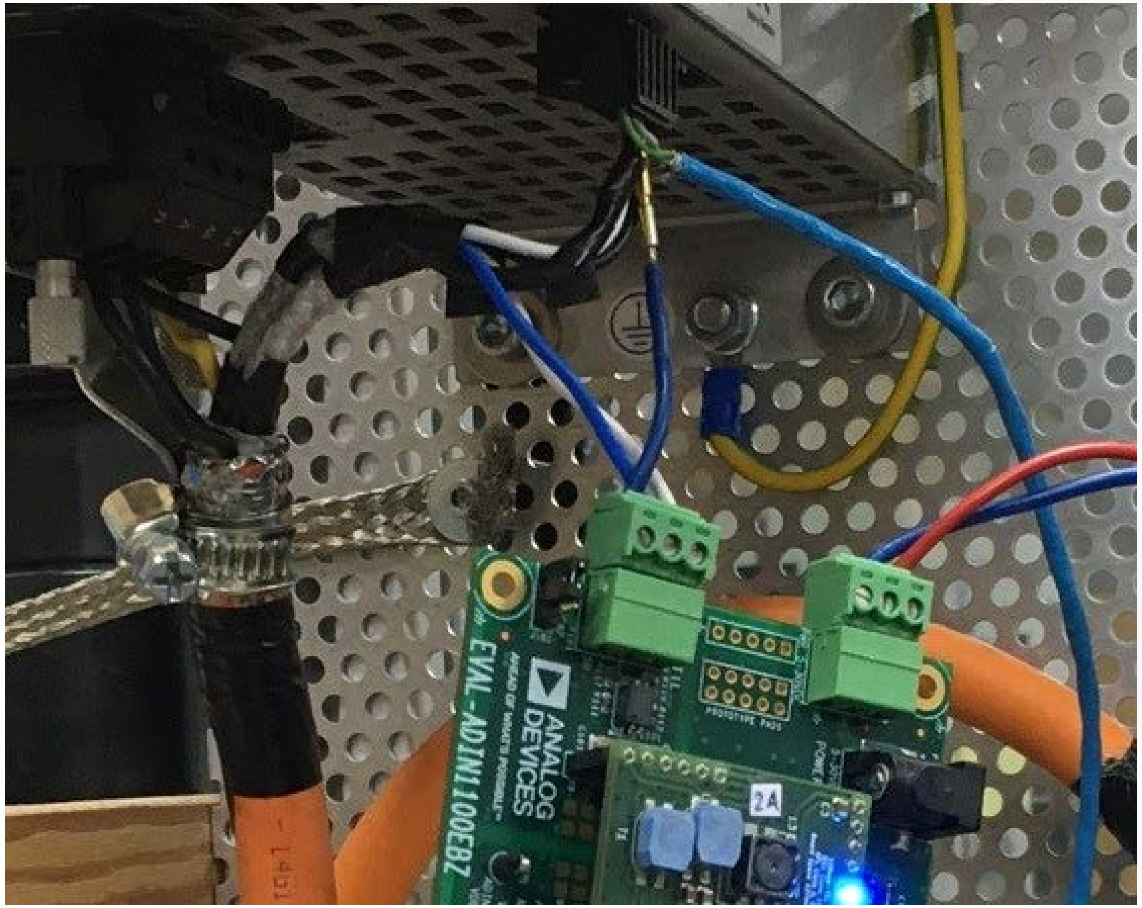
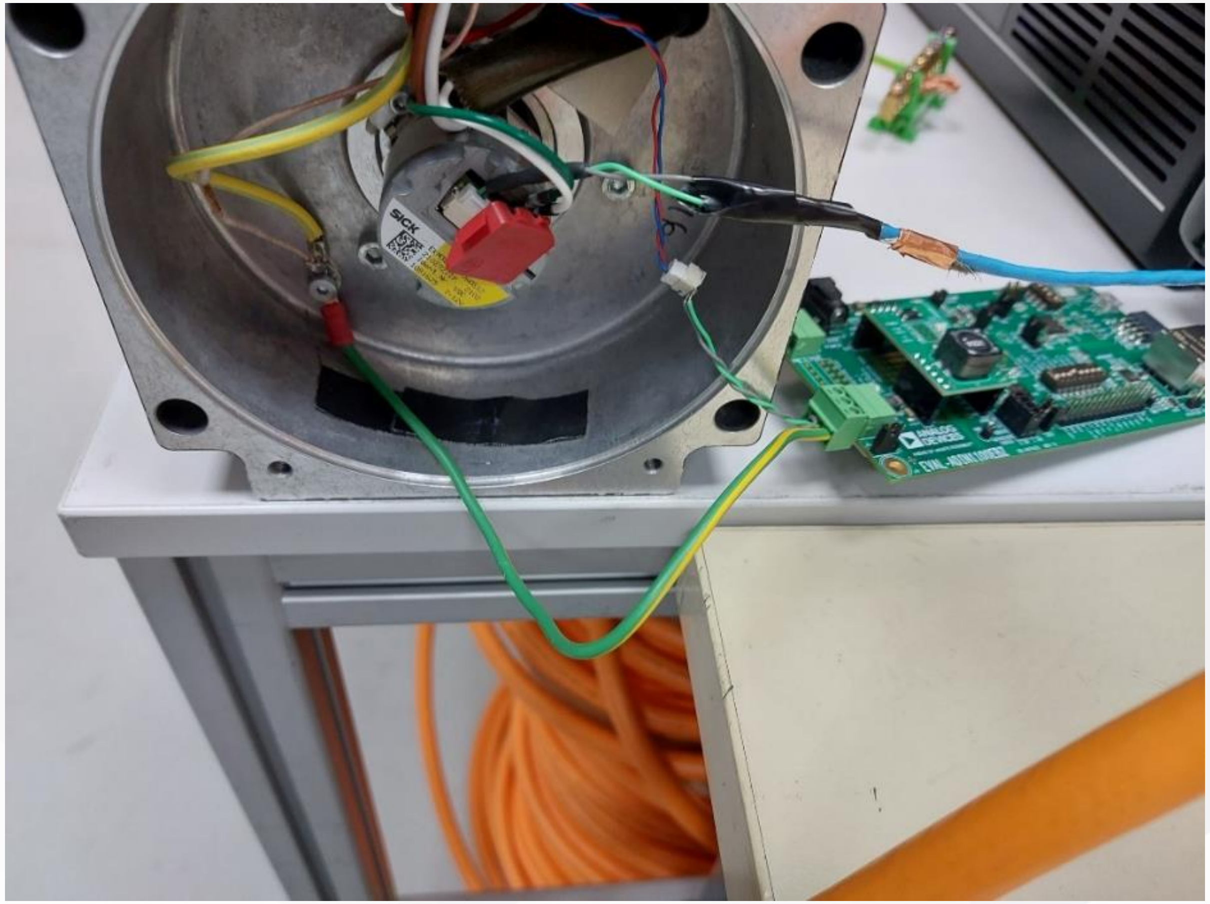
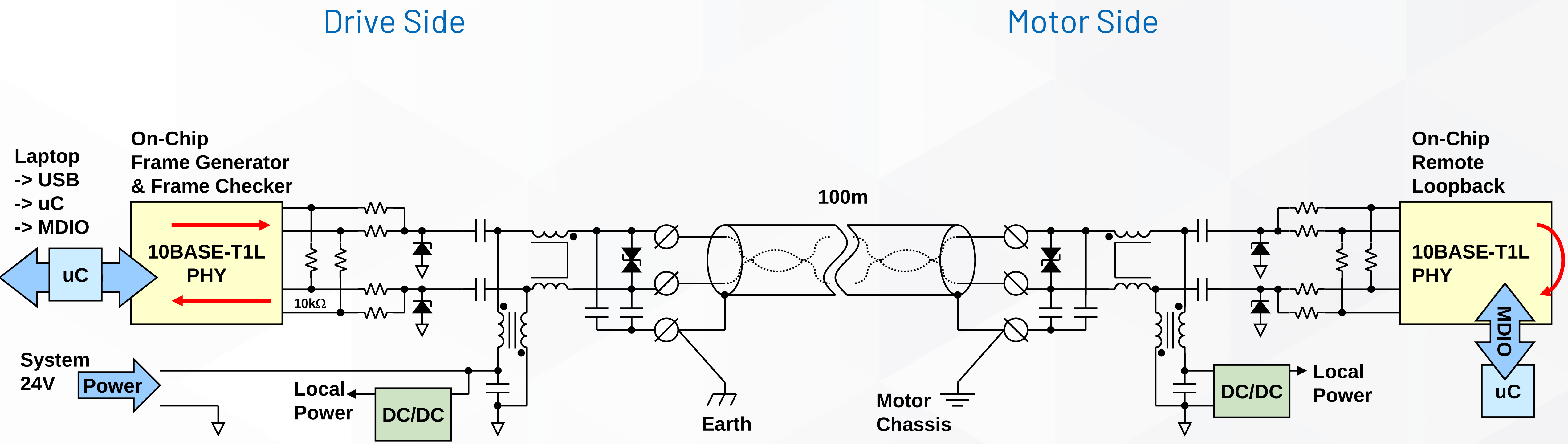
Drive Side



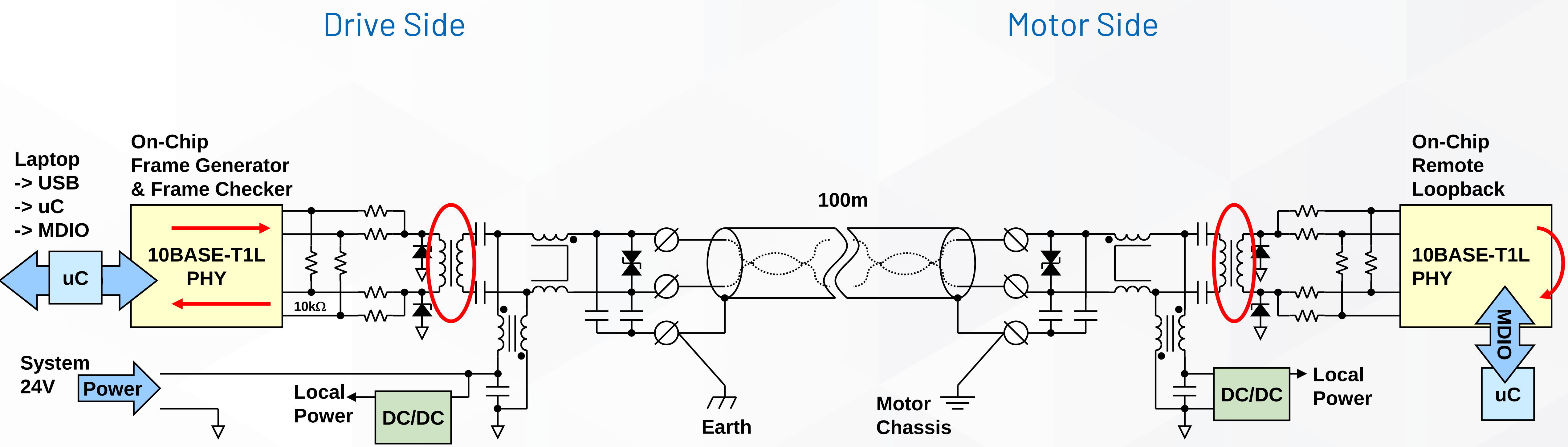
Motor Side



MDI Capacitively Coupled



MDI Transformer Coupled



10BASE-T1L Performance

Motor Control Hybrid Cable	10BASE-T1L Coupling	10BASE-T1L Amplitude	ADIN1100 MSE	ADIN1100 Slicer error	Errors / Frames	Frame Error Rate
Standard	Capacitive	2.4V	-31dB	0.81	78 / 50,000	0.16%
Standard	Capacitive	1V	-21dB	0.93	4,000 / 50,000	8.00%
Standard	Transformer	2.4V	-32dB	0.30	0 / 50,000	0.00%
Standard	Transformer	1V	-25dB	not recorded	3650 / 50000	7.30%
Advanced	Capacitive	2.4V	-37dB	0.10	0 / 50,000	0.00%
Advanced	Capacitive	1V	-32dB	0.18	0 / 50,000	0.00%

Summary - Conclusion

- The primary purpose of this activity was to see performance of 10BASE-T1L communication in this application
  - Reliable communication on “standard” hybrid cable only with transformer coupled ADIN1100 MDI
  - Reliable communication on “advanced” hybrid cable with both capacitive and transformer coupled ADIN1100 MDI
- Presented to IEEE802.3dg as some of the results may be of interest / relevant to the 100BASE-TL
  - Hybrid motor cable already identified as one of the target applications
  - Couple of cables measured in lab in context of this application
- Outcome
  - Various cables with different internal structure available for the same application
  - The cable structure has significant impact on the noise coupled between motor power and communication
- Suggestions
  - Check multiple cables and find worst applicable case
  - Measure the cable internal coupling using a network analyzer
  - Consider / try to capture worst case scenario motor driving signal (max voltage, max current, max rise/fall slew rate)
  - Consider extending measurement beyond 50MHz bandwidth
    - Depending on modulation chosen, 100BASE-T1L may need to be assessed in wider then 50MHz

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Thank You

Questions?