



PWM Noise and Its Induced Differential Noise

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Purpose

- Understand PWM noise path
- Characterize PWM noise and its induced differential noise

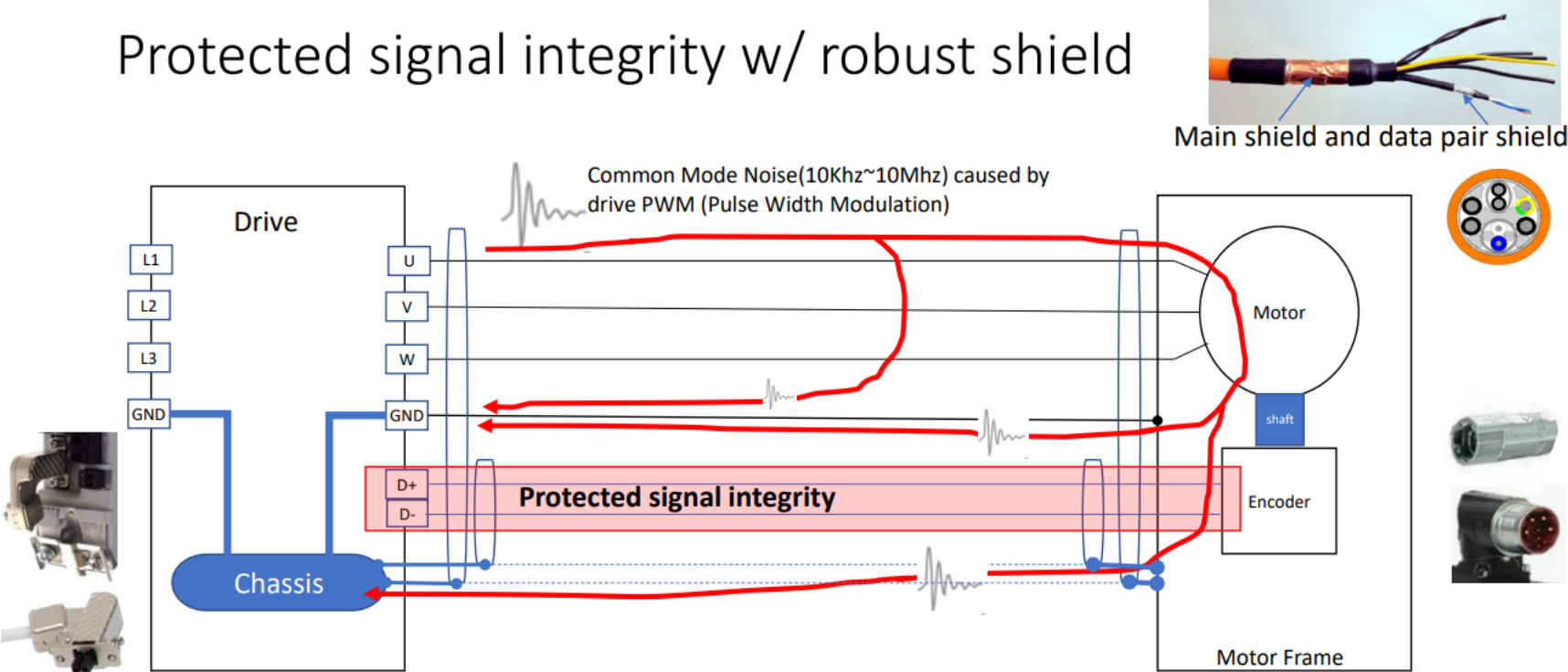
Related contributions

- Standardization activities related to servo drives, Bernd Horrmeyer
 - Discuss standards related to servo drives
- Cable and cabling capabilities to suppress differential and common mode noise, Peter Fischer
 - Discuss existing cable and cabling's CA and MC
- Questions:
 - **What does the PWM noise look like?**
 - **How much impact of PWM noise on the differential signal?**

Related contributions

[100BASE-T1L for Motor Feedback Communication, Dayin XU](#)

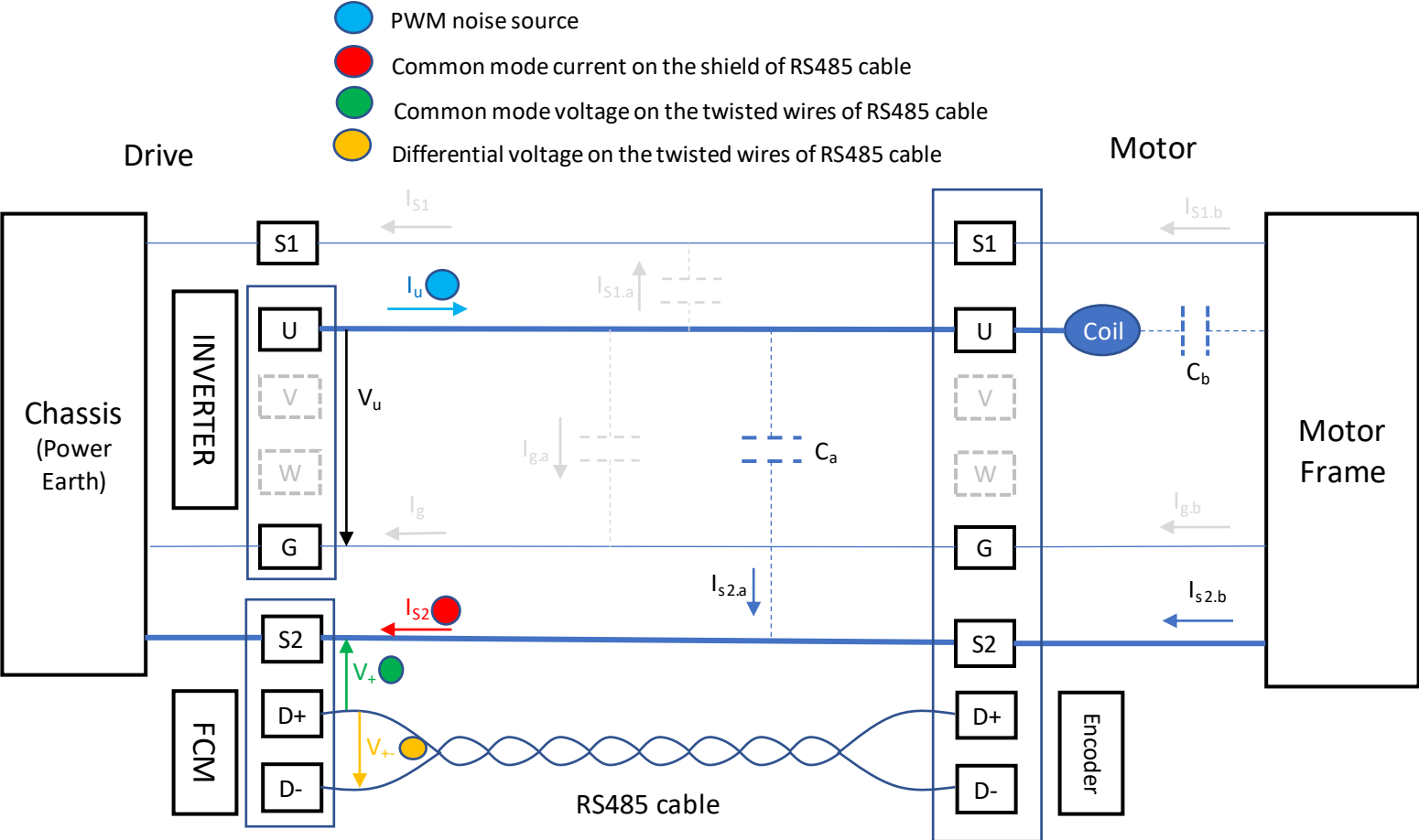
Protected signal integrity w/ robust shield



Robust shielded cable(>85% braided shield + foil shield) and shielded connectors minimize the cross talk from power wires to data wires and protect signal integrity of digital feedback communication

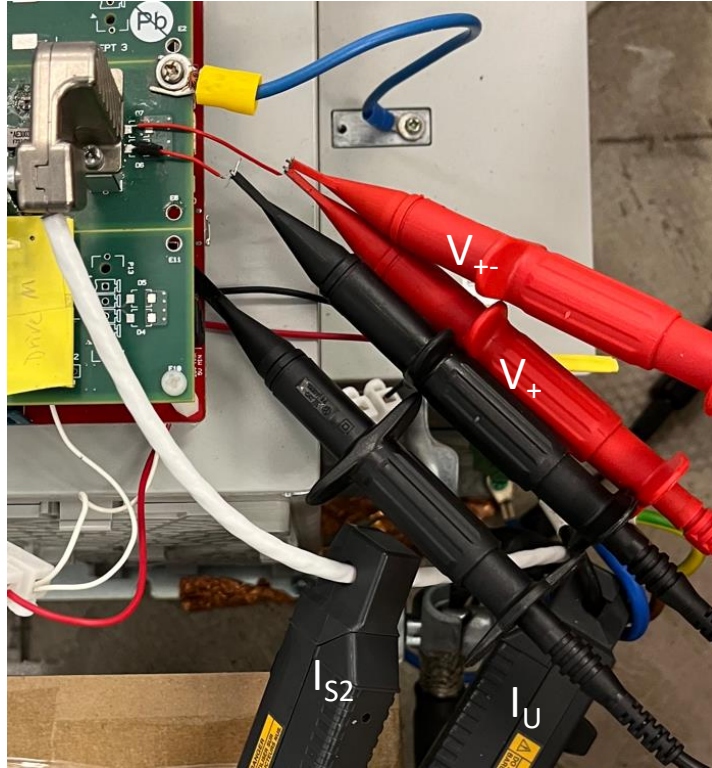
PWM noise path and measurement points

- PWM noise source
 - Inverter output voltage transient dv (e.g., 0V to 650V)/ dt (e.g., 200ns rise time), frequency range 10Khz-10Mhz with the bulk around 1Mhz
- PWM noise path
 - Common mode current ($I=C*dv/dt$)
 - Coupling Attenuation (a_c)
 - Screen attenuation (a_s)
 - Unbalance attenuation (a_u)
- PWM noise victim
 - Differential voltage signal at Encoder and Drive's Connector

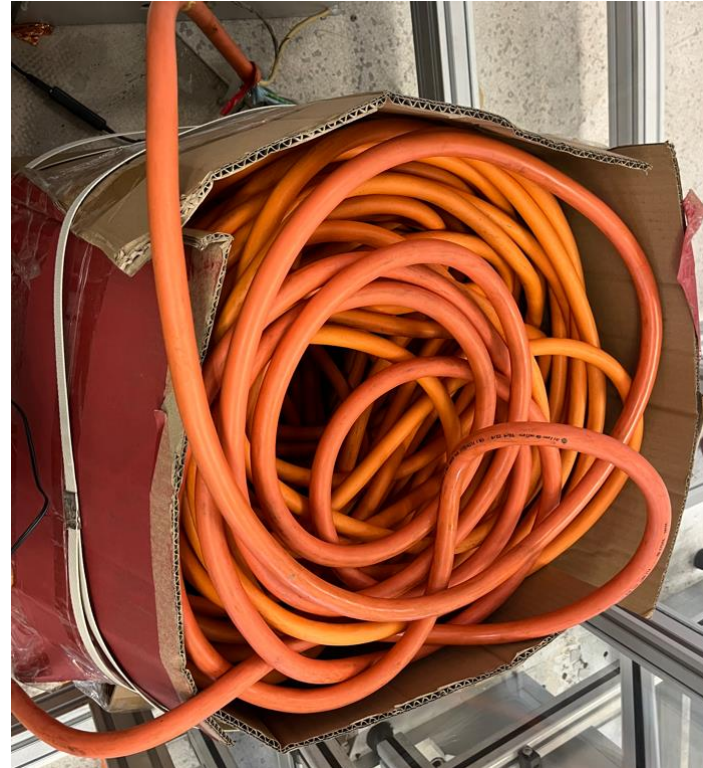


Measurement 1 setup

- 11.5V DC coupled onto the signal pair



Drive, adaptor board, and probe



90m hybrid cable

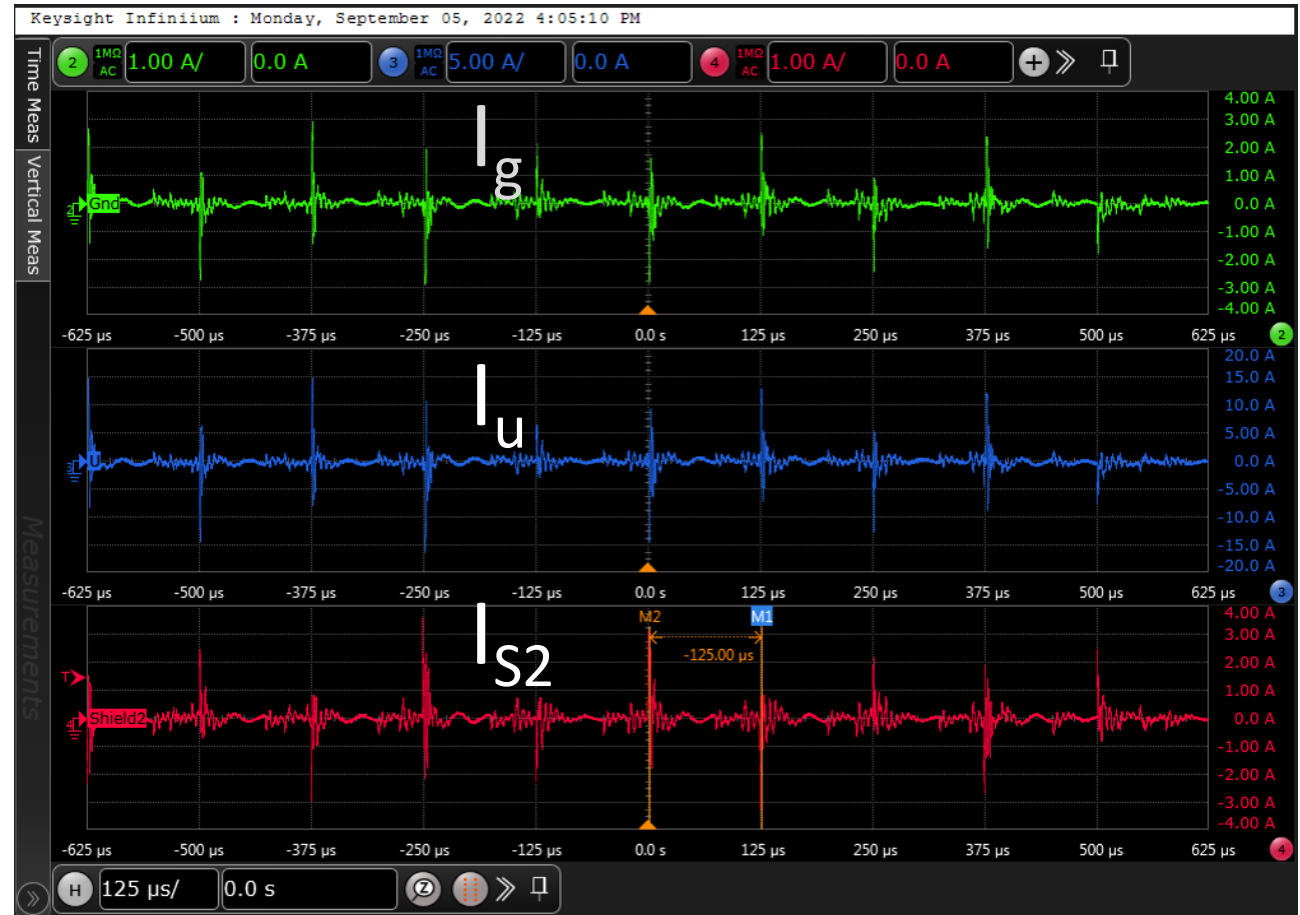


Servo Motor

Measurement 1 common mode current

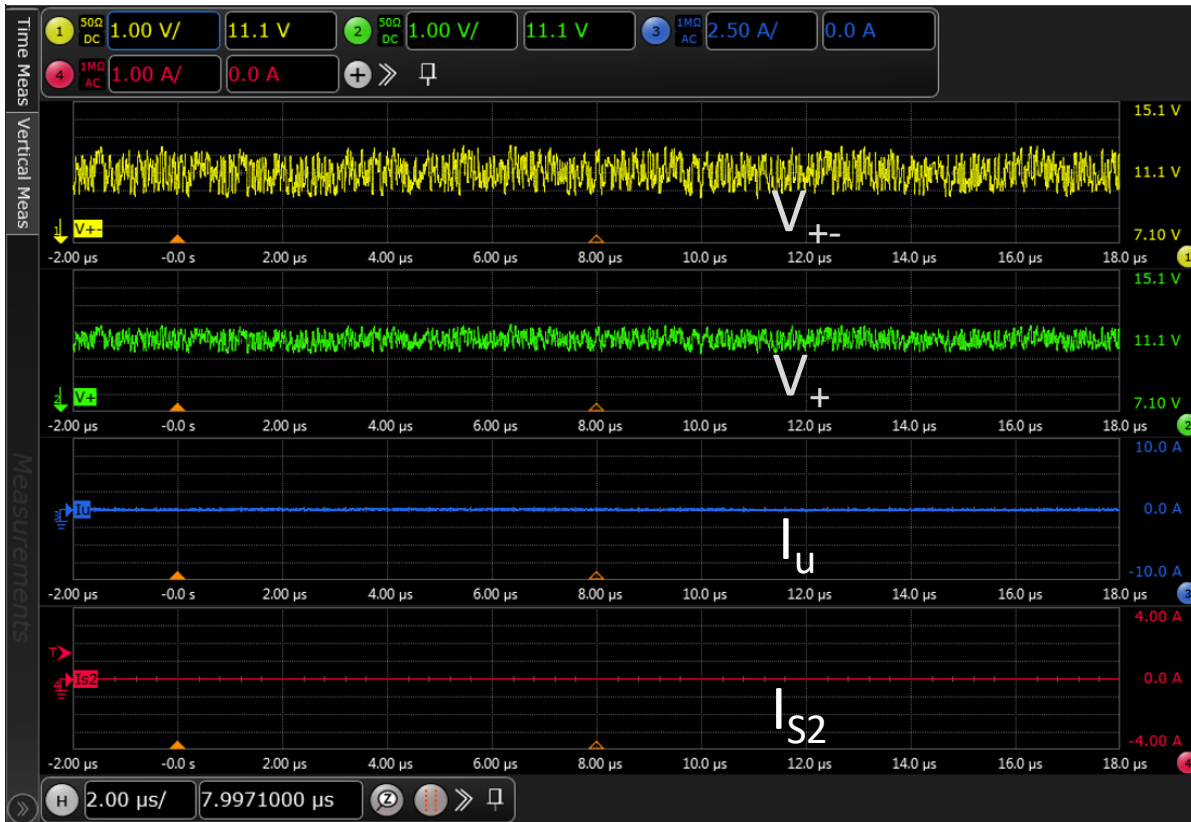
Repeated noise @ 8Khz

The peak-peak common mode current on the signal cable shield (Is2) is less than 8A

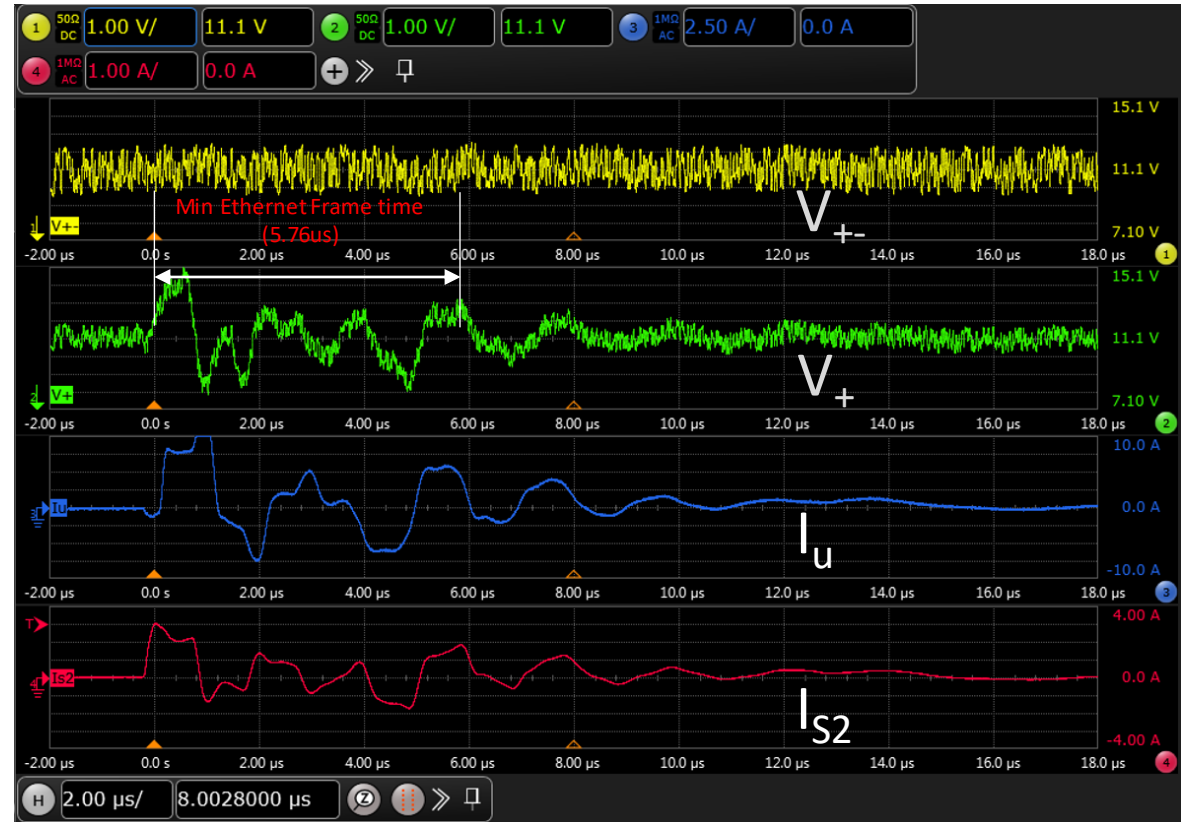


Measurement 1 – 100BASE-T1 differential signal

W/o PWM Switching Noise



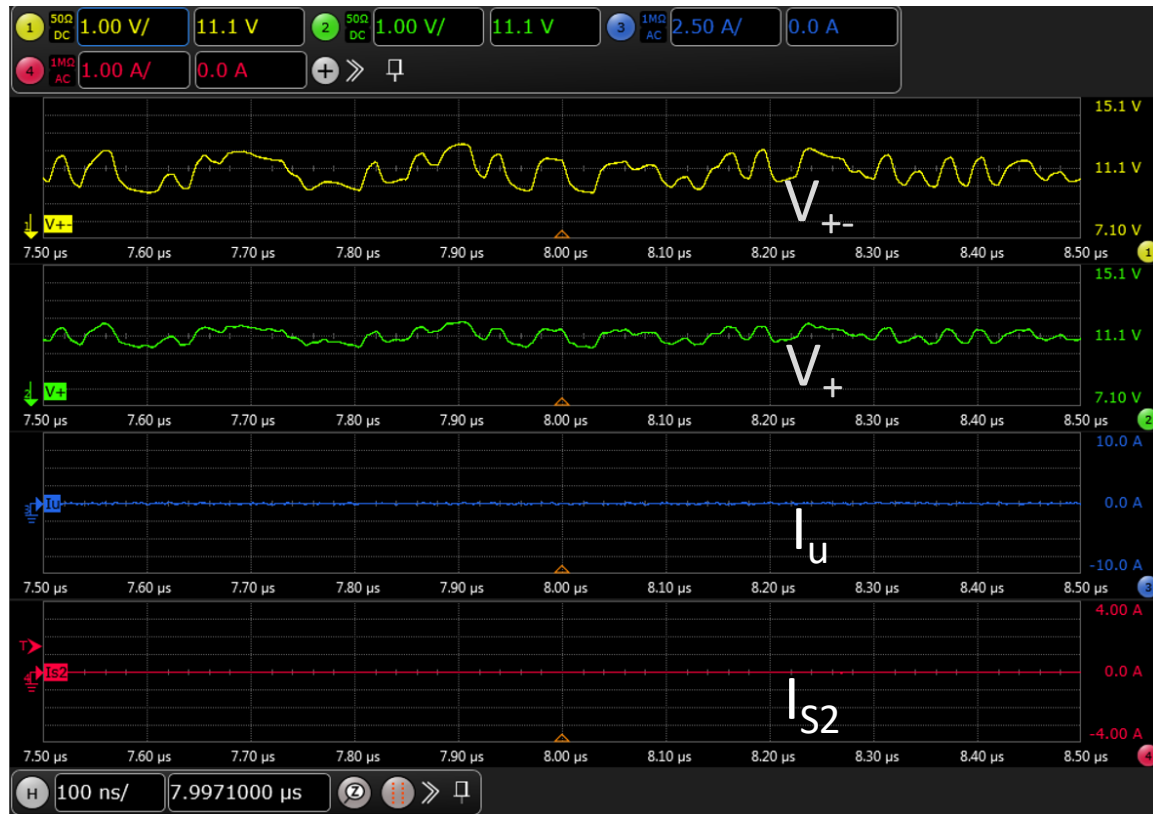
W/ PWM Switching Noise



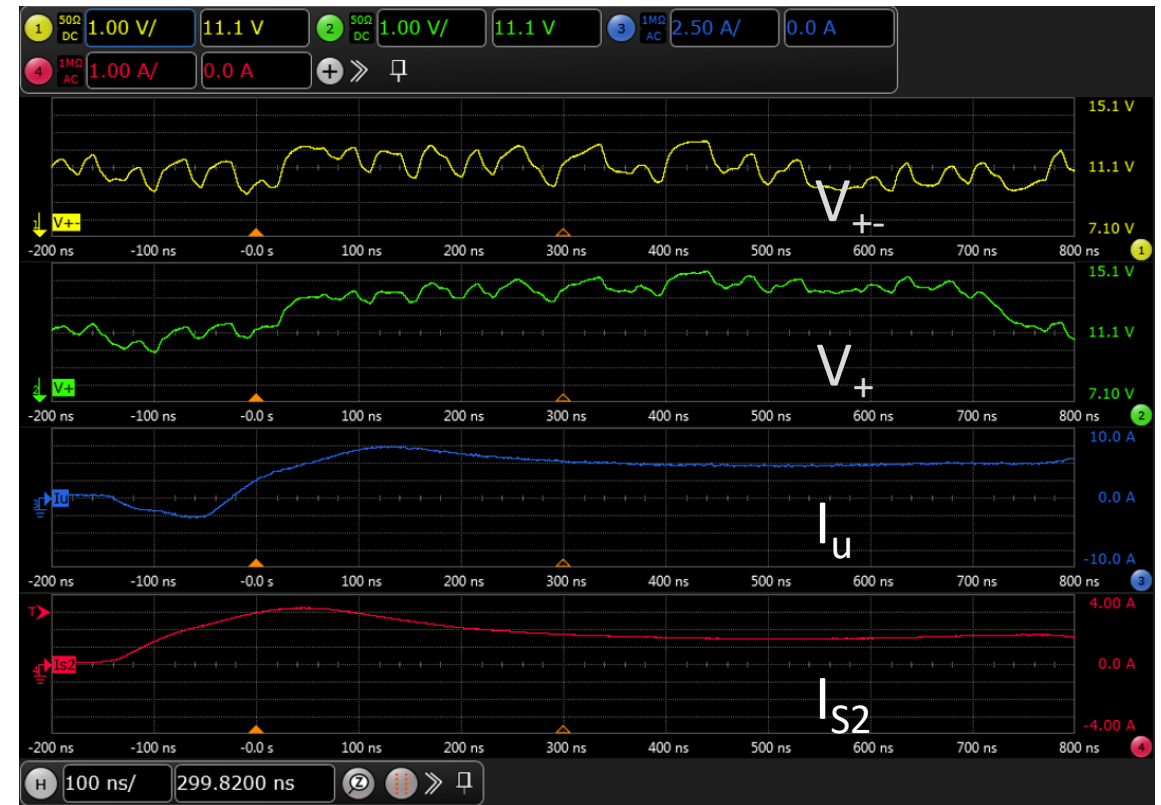
The peak-peak common mode voltage is less than 10V, the frequency is less than 10Mhz

Measurement 1 – zoomed differential signal

W/o PWM Switching Noise



W/ PWM Switching Noise



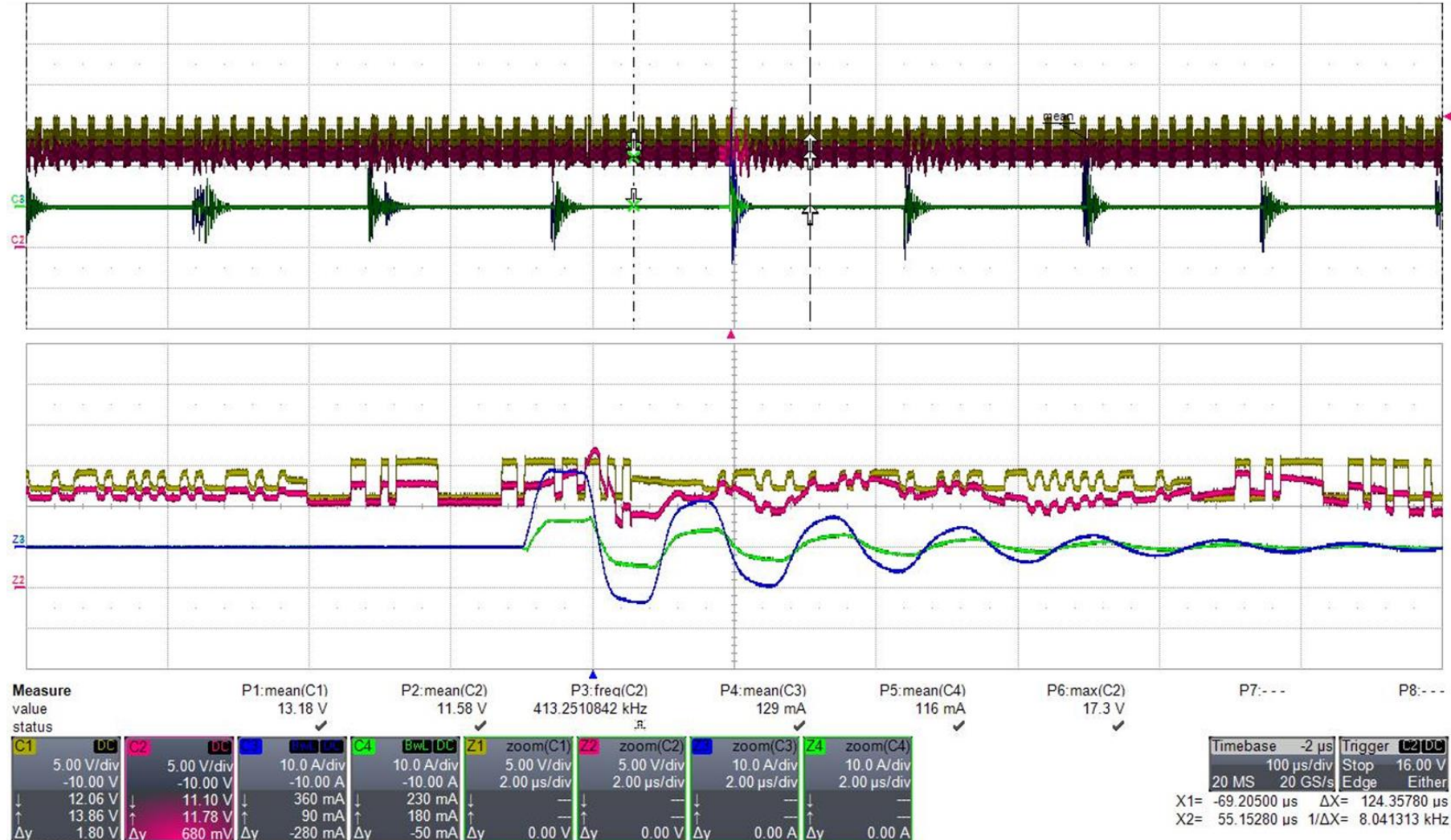
The rise time of common mode voltage is about 200ns, which is determined by IGBT switching time

Measurement 2 - RS485 differential signal

Note: waveform measured in years ago

Similar common mode noise waveforms to measurement 1

- Ch1(Yellow): V_{+} , differential signal
- Ch2(Pink): V_{+} , single end signal or 12V+ supply, referenced to common
- Ch3(Blue): I_U , U wire current
- Ch4(Green): I_g , ground wire current

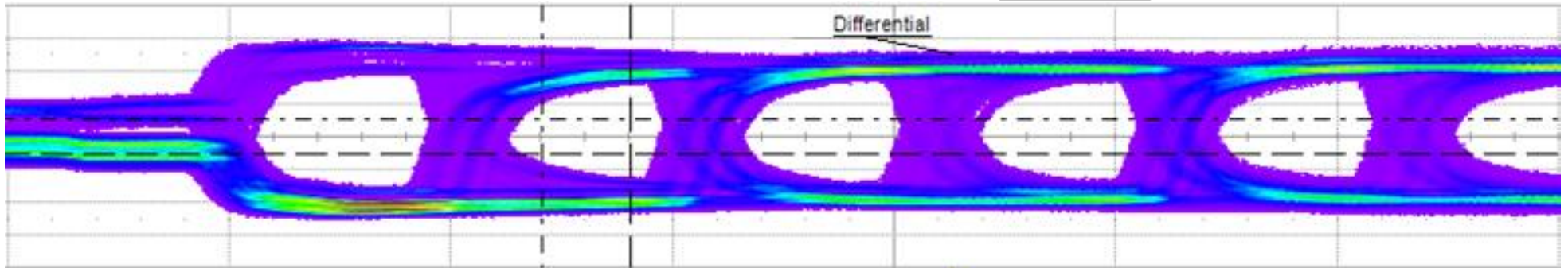


- 9.375Mbps RS485
- 12V DC coupled onto RS485 pair
- 90m motor cable
- 8Khz PWM Switching Frequency
- **200ns rise time** of common mode noise, which is determined by IGBT switching time
- **< 10V peak-peak** common mode voltage noise

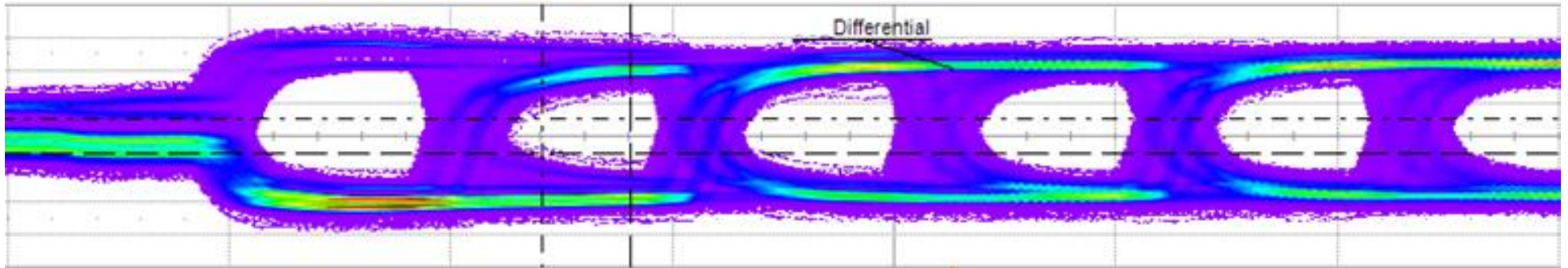
Measurement 2 – RS485 differential signal eye diagram

C1	DC	Timebase	26 ns	Trigger	C3 DC
	500 mV/div		100 ns/div		Normal 1.76 V
	0.0 mV ofst		2.5 GS/s		Qualified Pos
----	250 mV	X1=	-185 ns	$\Delta X=$	40.0 ns
.....	-250 mV	X2=	-145 ns	$1/\Delta X=$	25 MHz
Δy	-500 mV				

w/o PWM
Switching
Noise



w/ PWM
Switching
Noise



PWM switching noise does reduce the eye height a bit but does not impact the communication reliability since the eye height of the differential signal is still much higher than 500mV.

Summary

- Two measurements show similar common mode noise in motor feedback system, the common mode noise voltage level is less than 10V peak-peak
- The differential signal can communicate reliably under PWM common mode noise when there is a robust shield design for the motor cable

Ask

- Measure 100m link segment of standard AWG22 shielded SPE cable and cable assembly
 - Insertion Loss
 - Return loss
 - Coupling Attenuation (Screen Attenuation and Unbalance Attenuation)



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