Preliminary Drive Noise Measurements

David D. Brandt

Rockwell Automation

Purpose

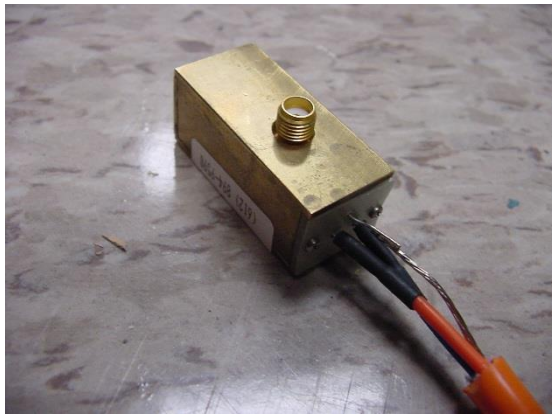
- The purpose of this presentation is to:
  - Present “first pass” measurements of Drive noise induced in a communication cable typical of the 1000 m link segment
  - Consider whether a more extensive evaluation is warranted

Drives

- Drives operate motors at variable speed from a fixed frequency (60 Hz) line
  - VFD = Variable Frequency Drive
- Typically 3Φ line voltage is rectified to DC (480 Vac -> 678 Vdc)
- The DC is switched in pulses via PWM to a 3Φ Motor cable, where the inductance in the motor integrates the current into a sinusoid
  - Typical PWM rate is 2-4 kHz, sometimes higher

- Drive cables, grounding, and proximity are significant and common sources of interference in industrial facilities

Communication link

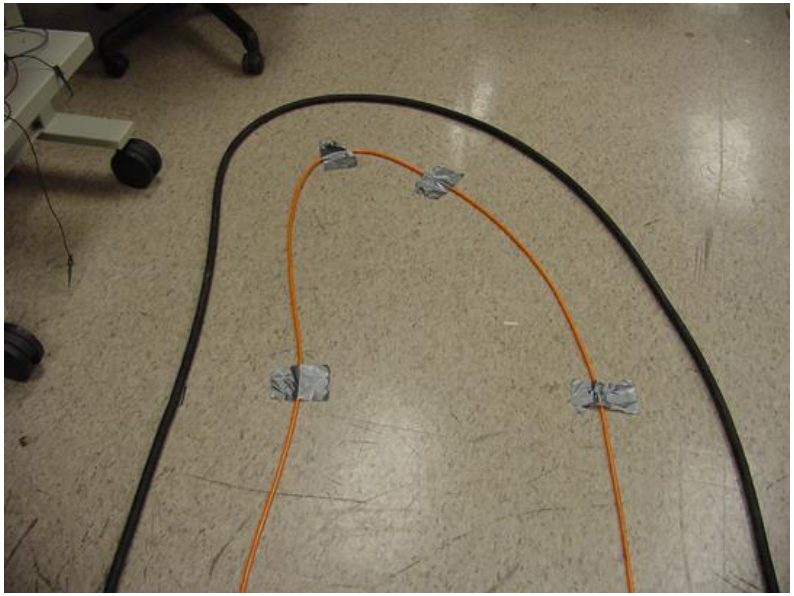


- Belden 3076F cable (10 m)
  - ISA/SP-50, FOUNDATION Fieldbus or PROFIBUS
  - 18 AWG stranded (7x26), twisted balanced pair, foil shield, drain wire, polyolefin insulation
- BH Electronics 040-0055 BALUN on each end
  - 100 Ω differential termination for cable pair
  - 50 Ω SMAs for measurement of CM and DM
  - Optional shield termination via case
  - 2.4 dB maximum insertion loss

Interference source

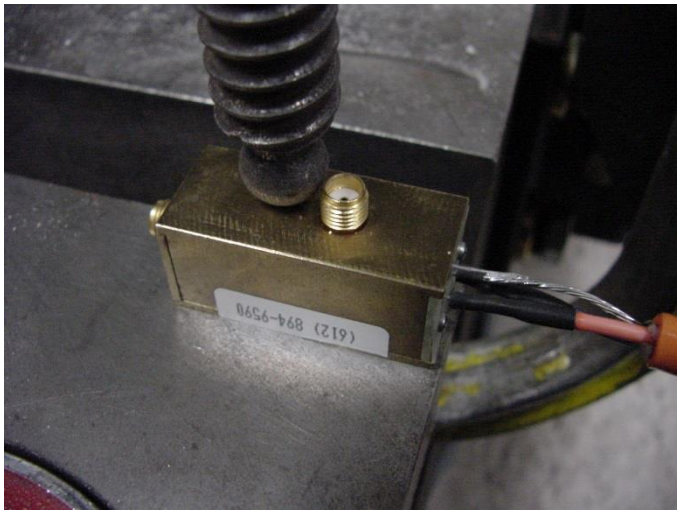
- Drive: PowerFlex 755, 7.5 hp
  - PWM configured to 12 kHz
- Motor: Reliance Electric Duty Master, 10 hp
  - No load
- Cable: Carol 4C 10 AWG
  - No Shield (systems below 10 hp are often unshielded)

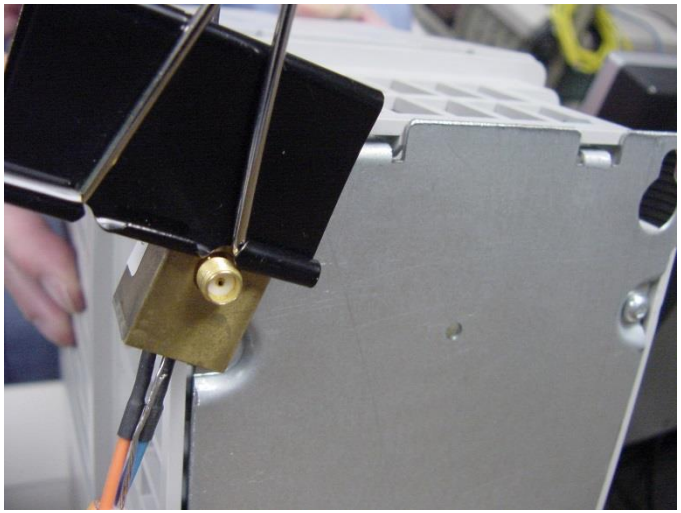
Cable placements



- The communication cable was placed in parallel to the motor control cable
- Two variations
  - Adjacent
  - Approximately 20 cm separation

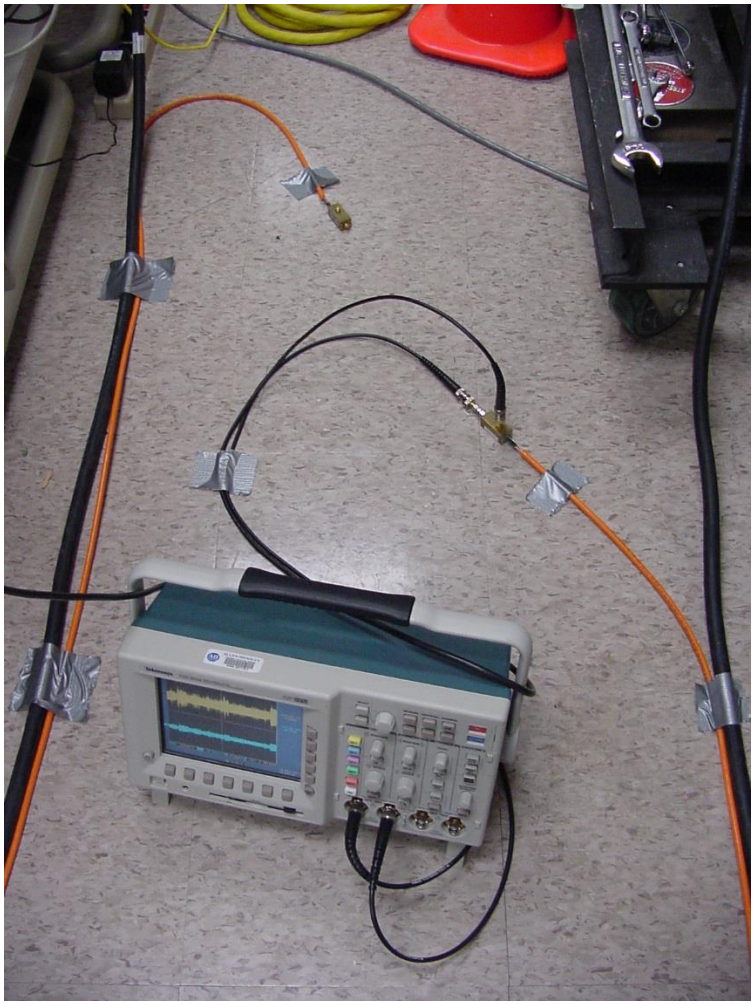
Communication shield termination





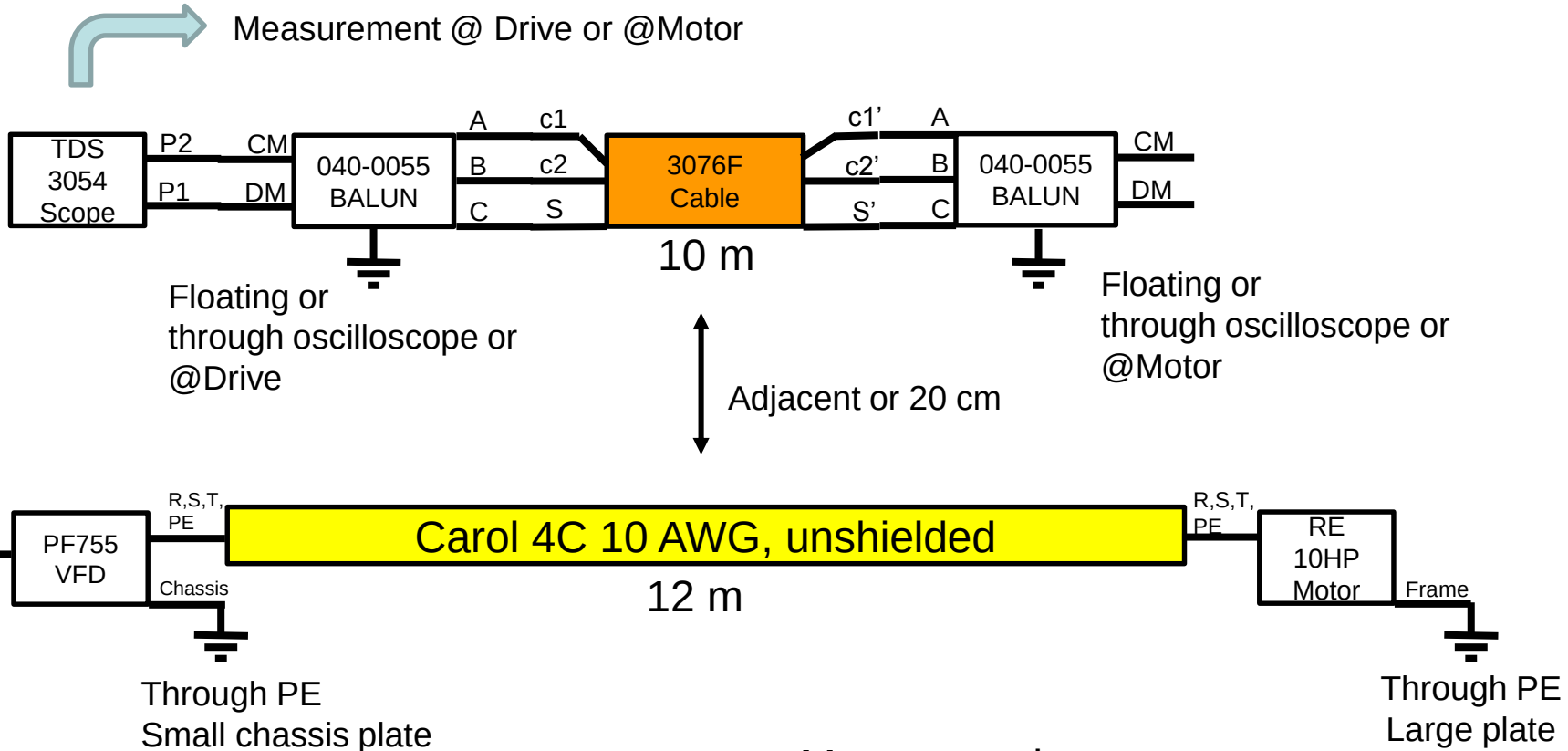
- The shield GND was through the BALUN
  - On the measurement, GND included the oscilloscope
  - On the other end in one of 3 ways:
    - Isolated from Drive and Motor
    - Tied to the Motor's frame ground via metal plate
    - Tied to the Drive's metal mounting plate

Measurements



- Tektronix TDS 3054, 500 MHz, 5 GS/s
- 2 channels attached to BALUN
  - Ch1 to BALUN CM
    - 50 Ω
  - Ch2 to BALUN DM
    - 50 Ω
    - 20 MHz BW limit
- FFT calculation

Setup summary



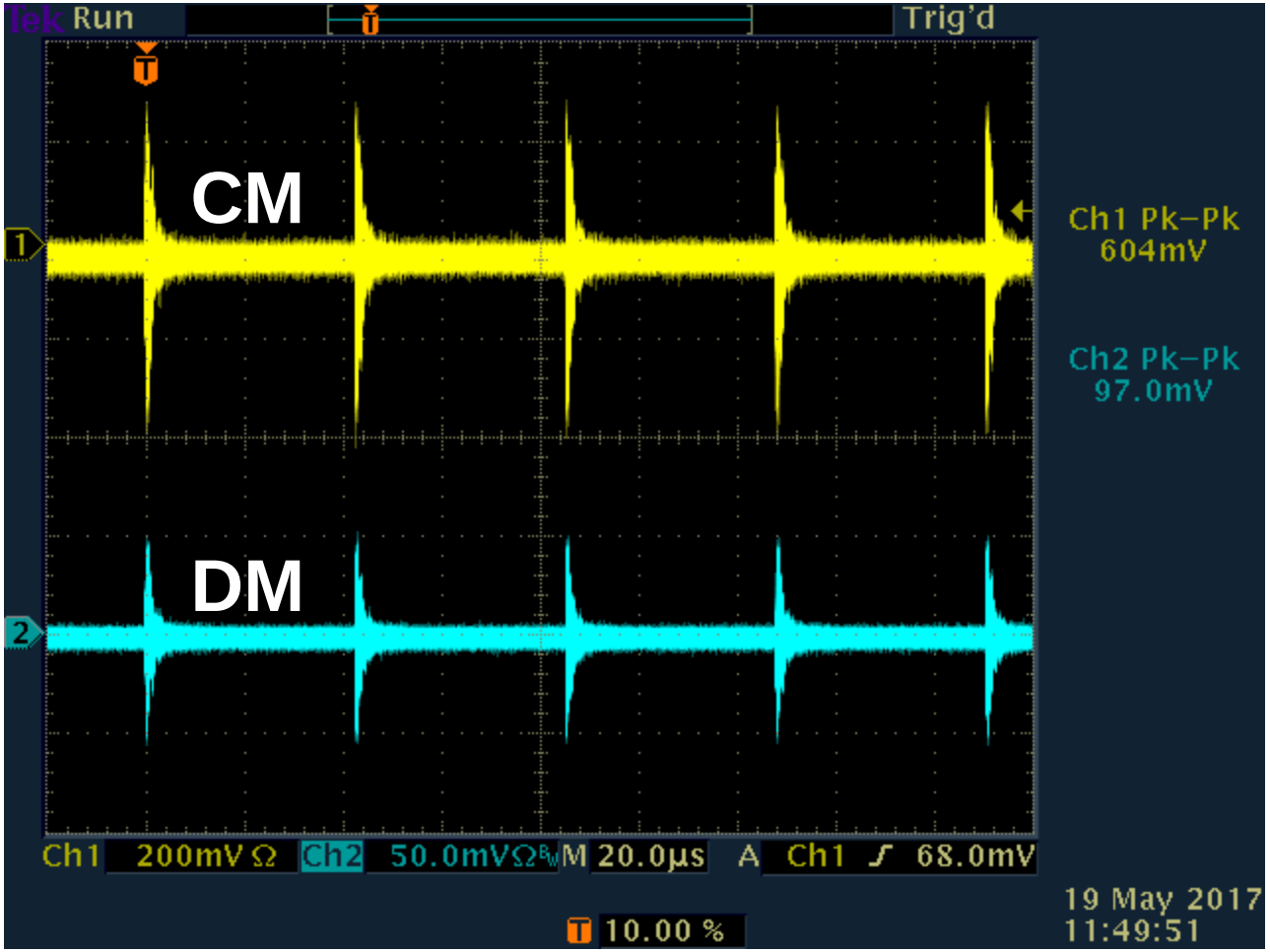
Motor speed

0 Hz is held in position

60 Hz is run at full speed

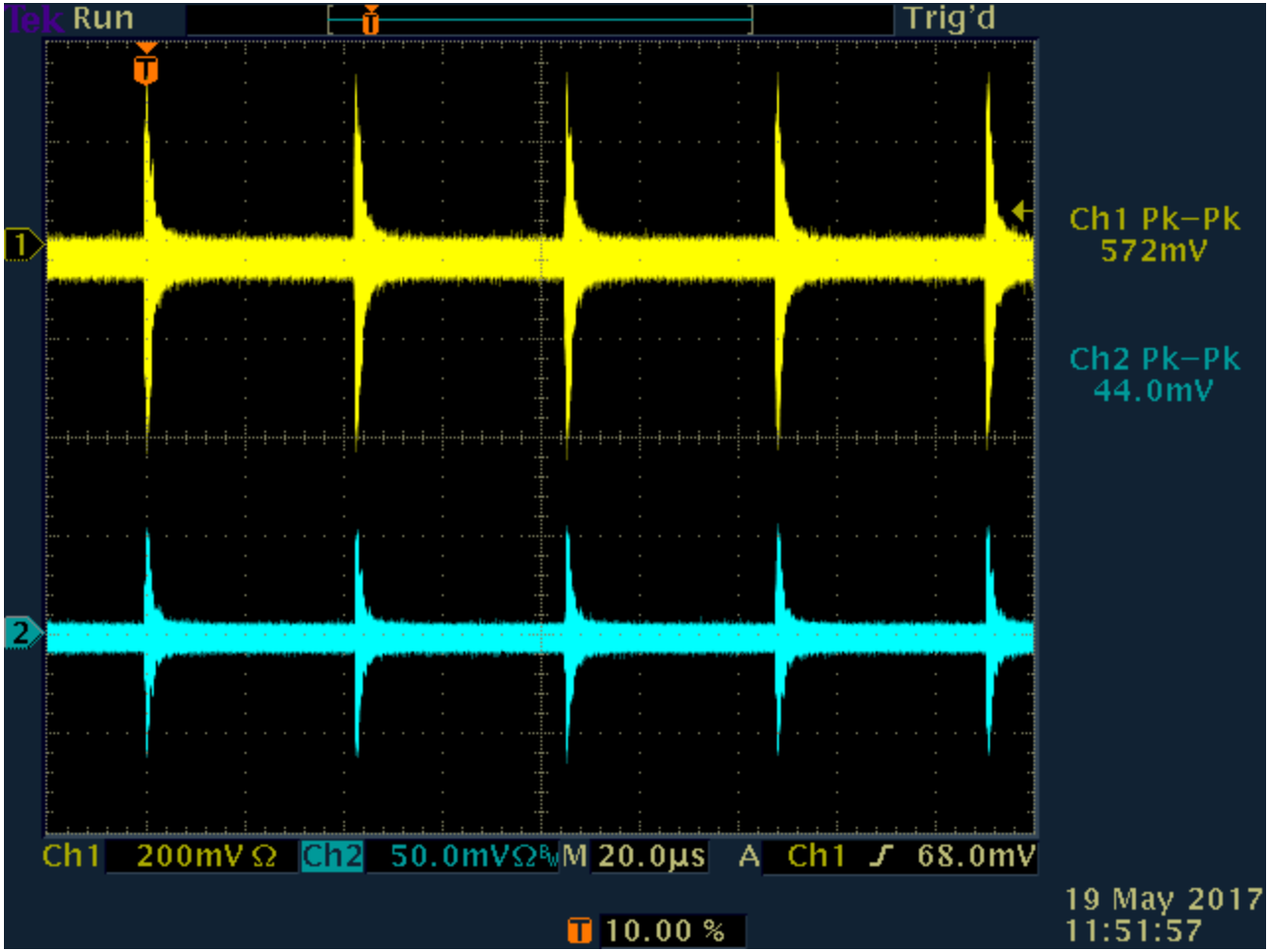
Testing with adjacent cables

Setup: Adjacent cables, Isolated GNDs, 0 Hz
Measurements: Drive end



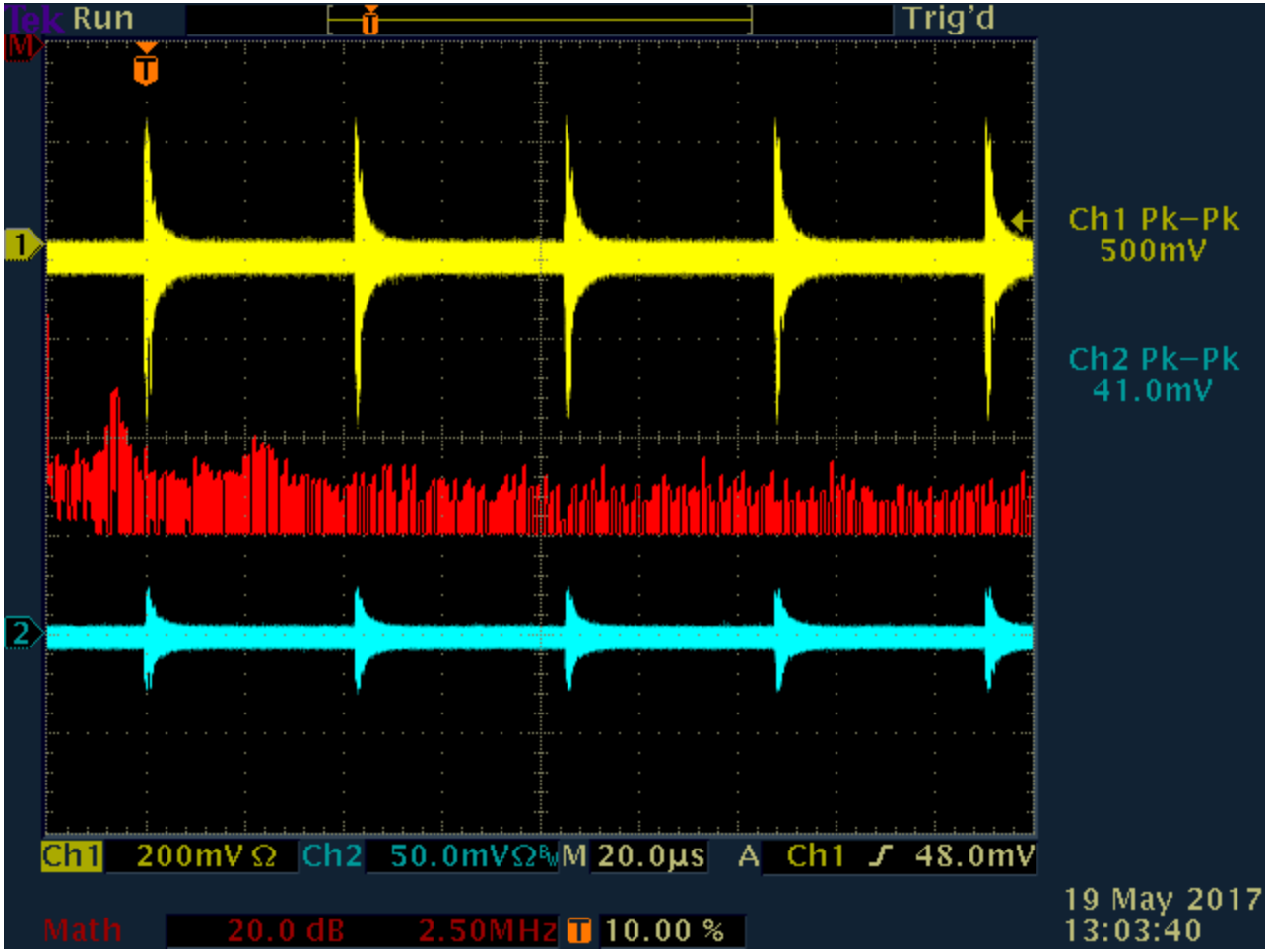
- ~6x voltage reduction
- ~24 kHz

Setup: Adjacent cables, Isolated GNDs, 0 Hz
Measurements: Motor end



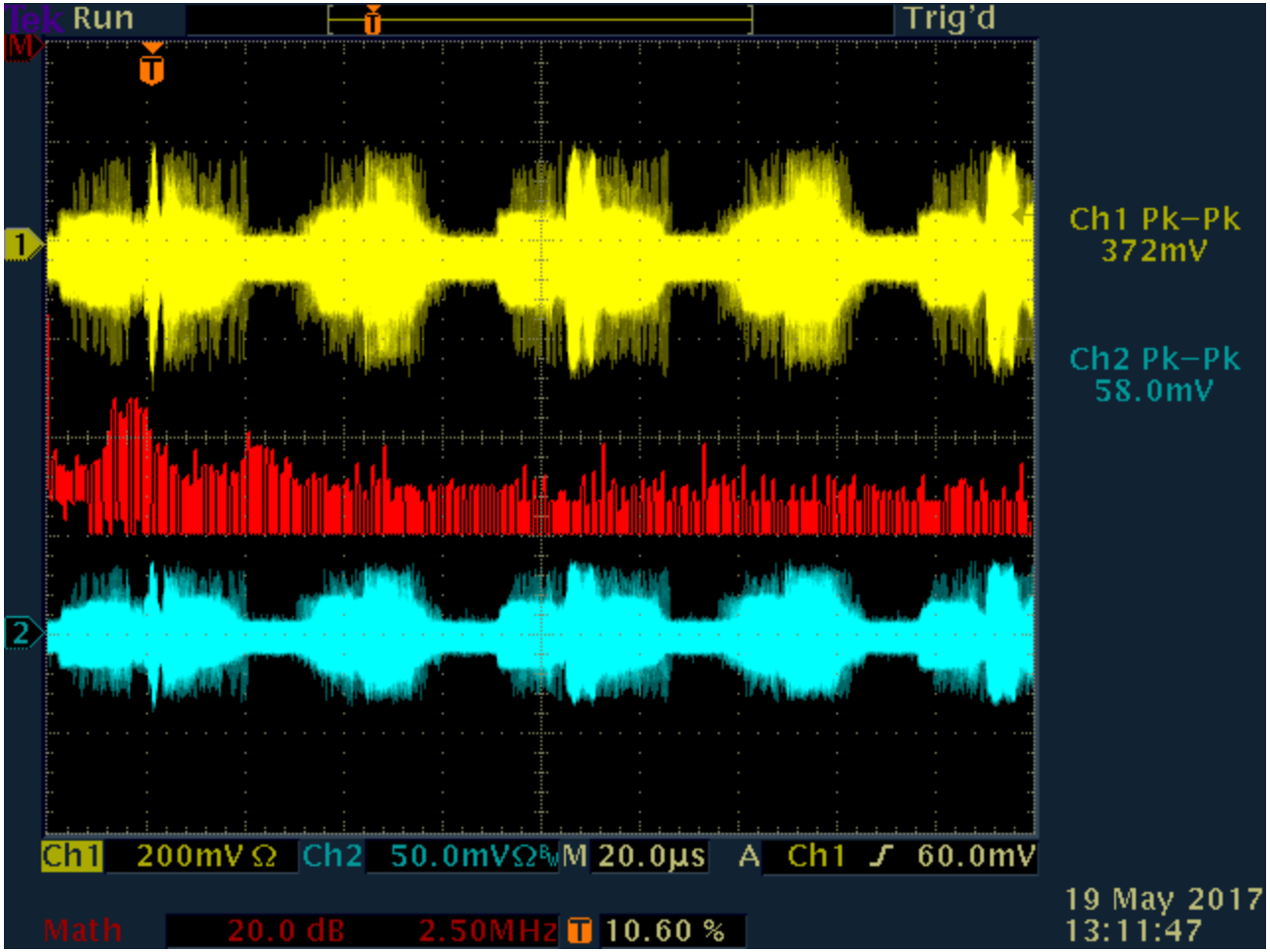
- CH2 visually appears to be 100 mV Pk-Pk
  - 50 mV differential
- Pk-Pk does not appear accurate

Setup: Adjacent cables, Isolated GNDs, 0 Hz
Measurements: Motor end



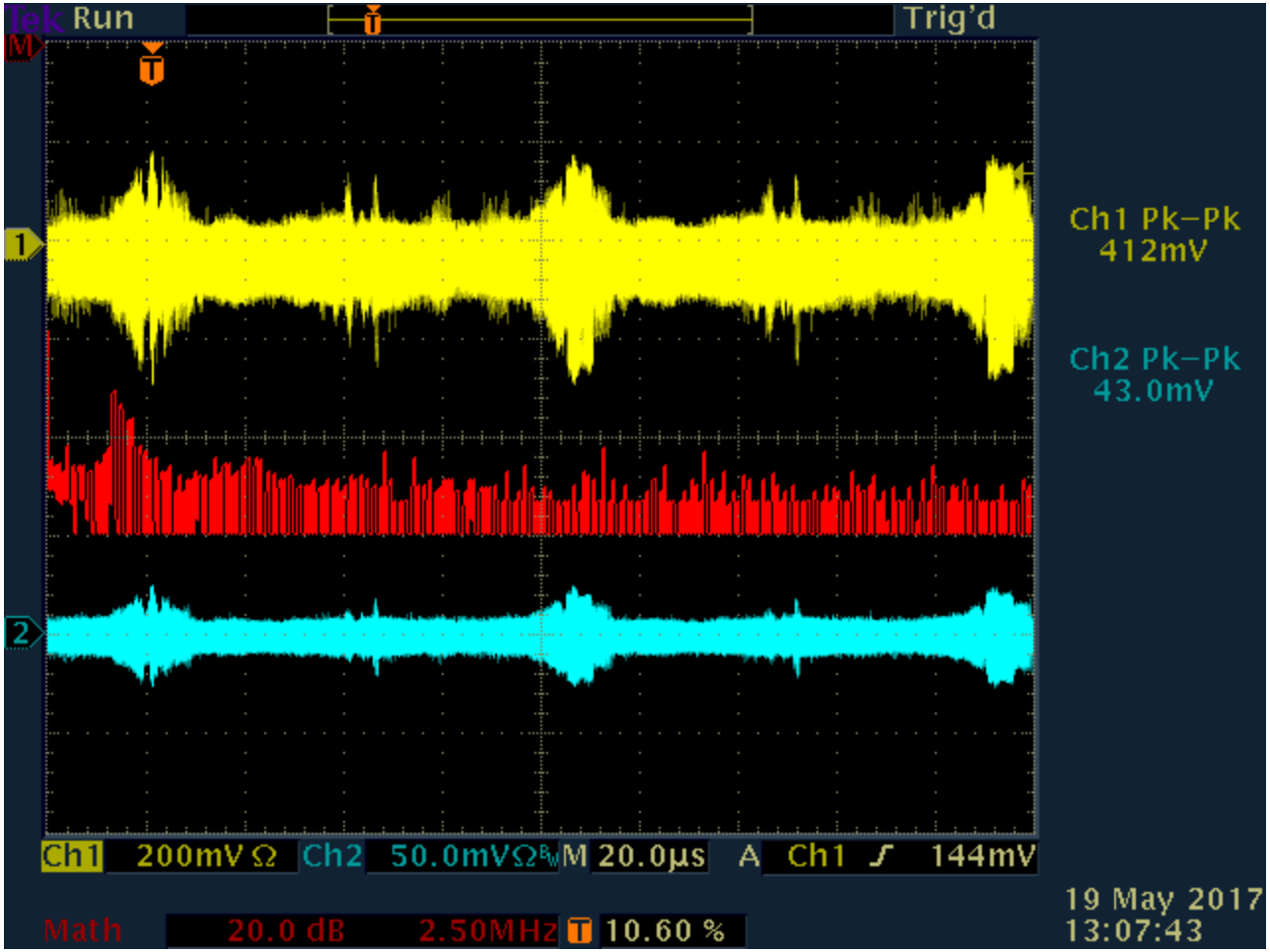
- Add FFT
  - Rectangular window
  - dBV
- 25 MHz span
- Pk between 1.5 - 2 MHz

Setup: Adjacent cables, Isolated GNDs, 60 Hz
Measurements: Drive end



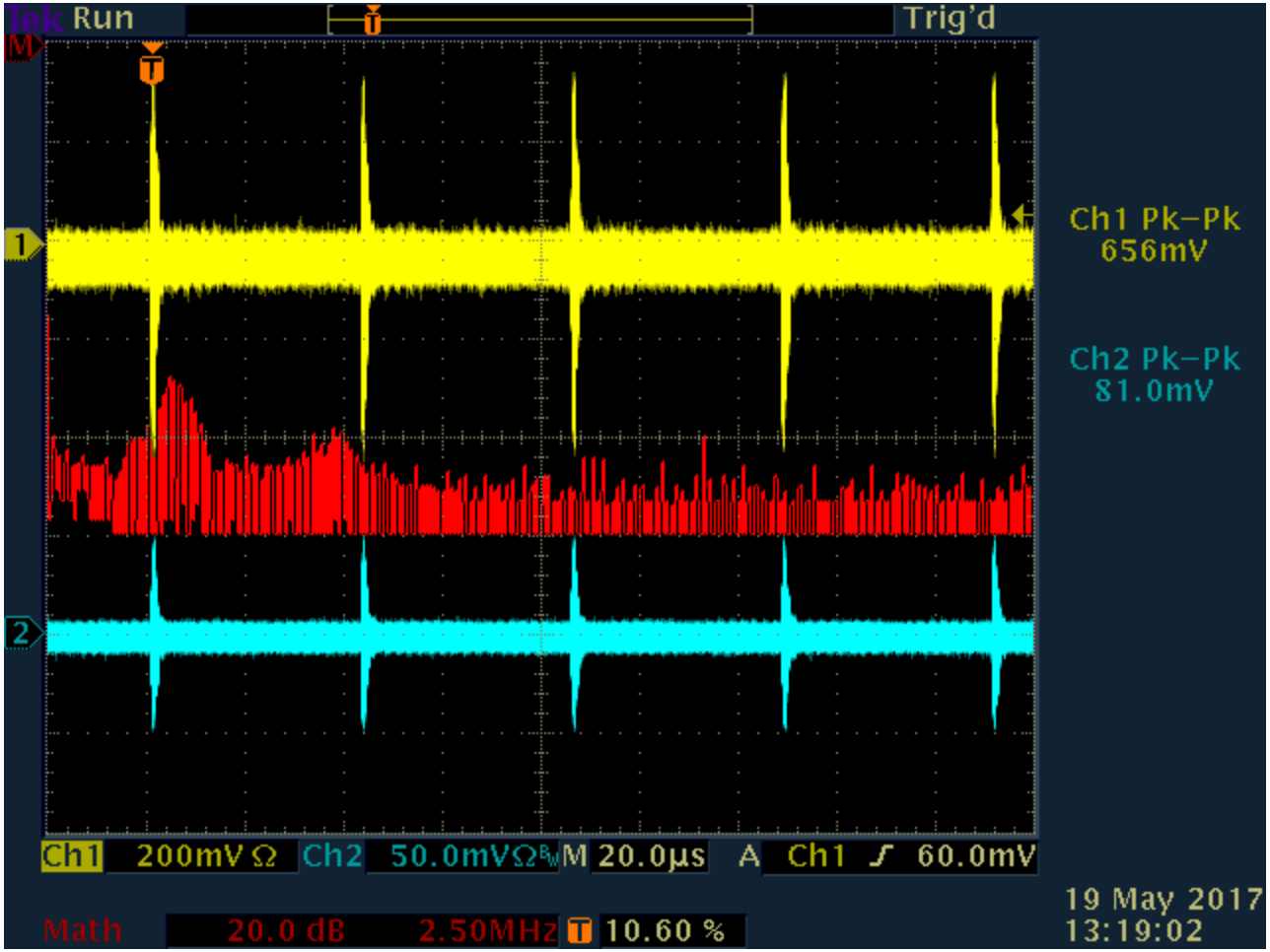
- Motor “at speed”
- Reduced peaks
- More noise between peaks

Setup: Adjacent cables, Isolated GNDs, 60 Hz
Measurements: Motor end



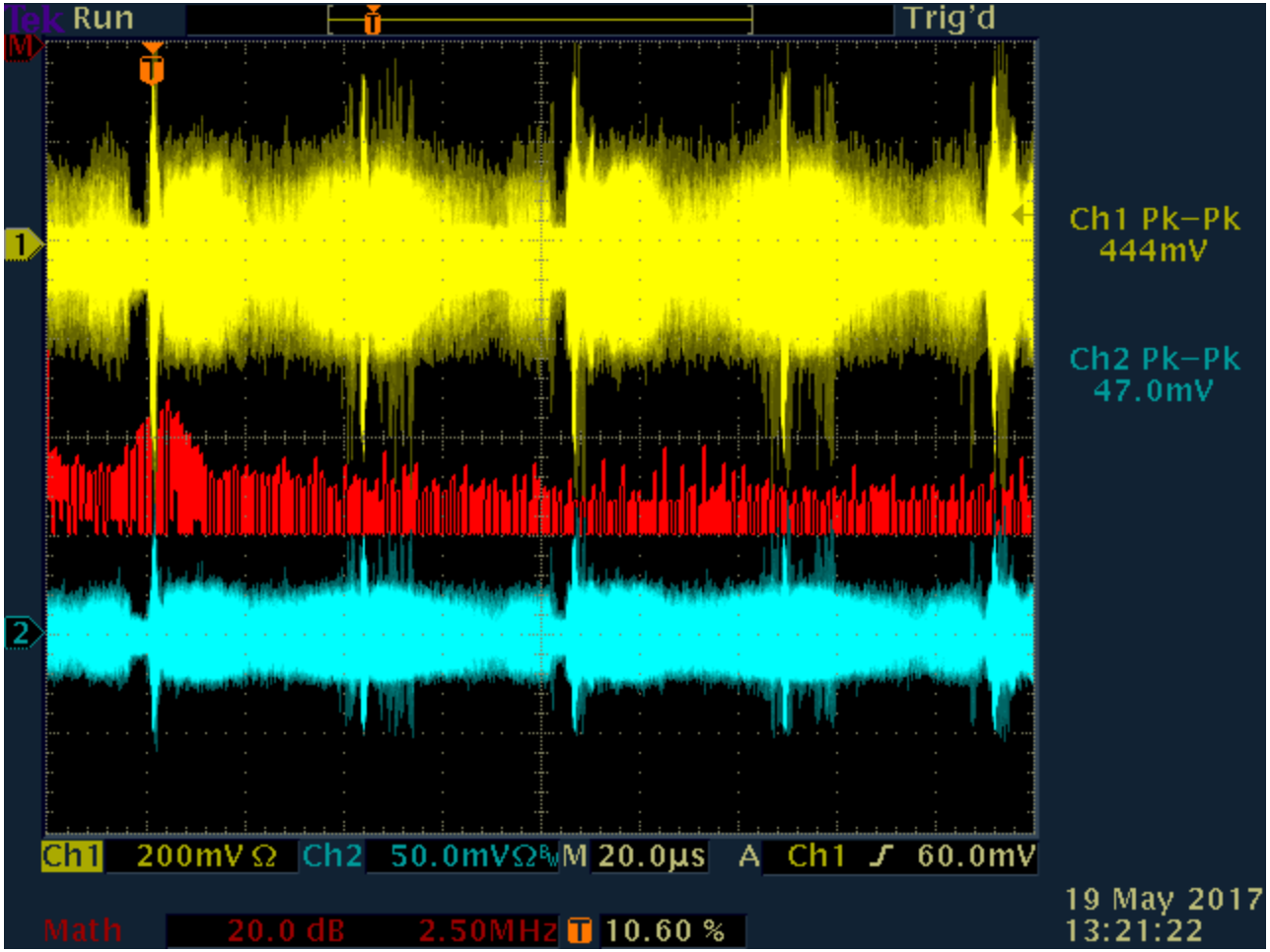
- Motor “at speed”

Setup: Adjacent cables, GND BALUN at motor, 0 Hz
Measurements: Drive end

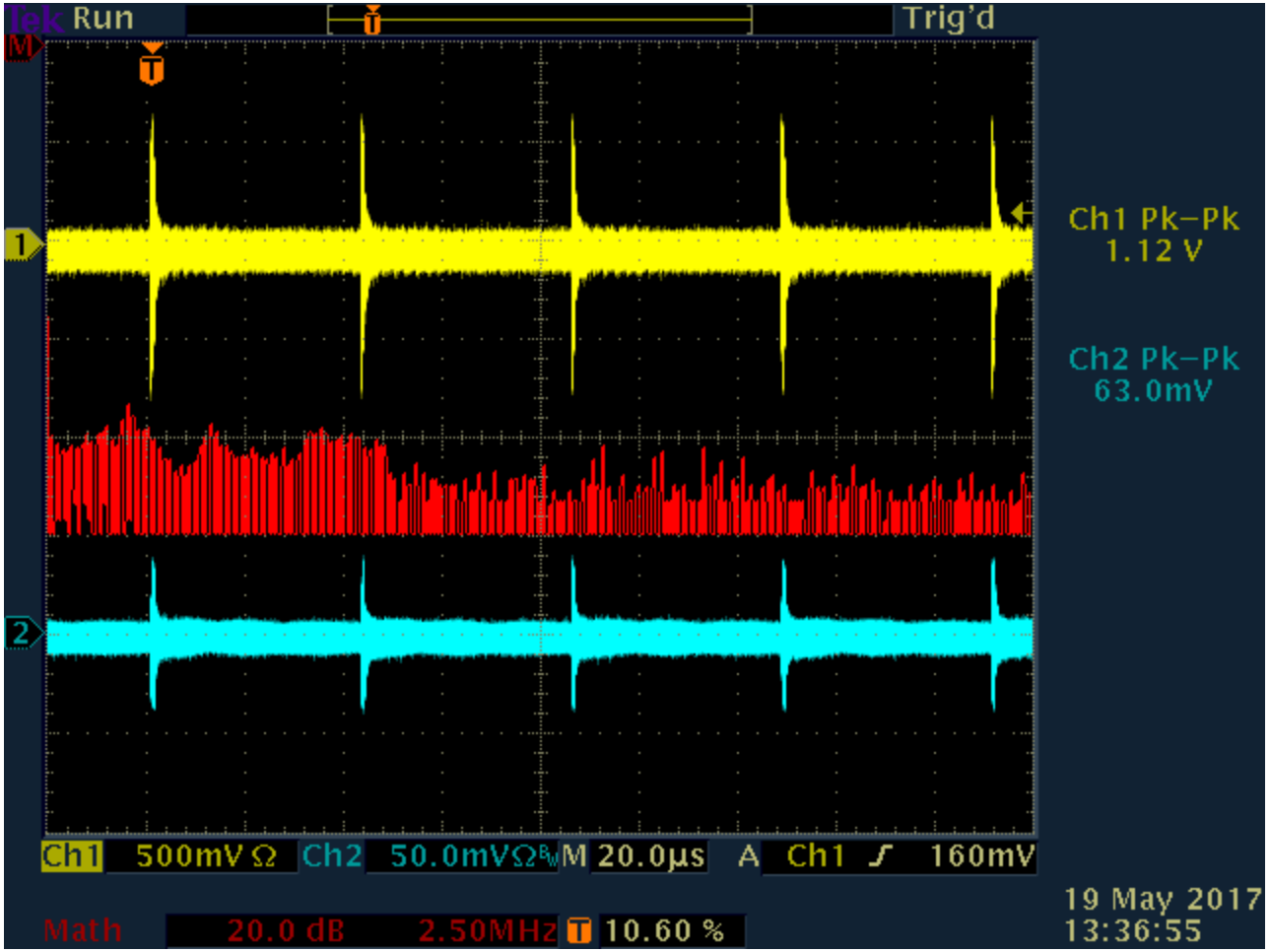


- Motor GND appears to add little to Pk noise
- ~8x voltage reduction
- FFT Pk about 3 MHz (shifted)

Setup: Adjacent cables, GND BALUN at motor, 60 Hz
Measurements: Drive end

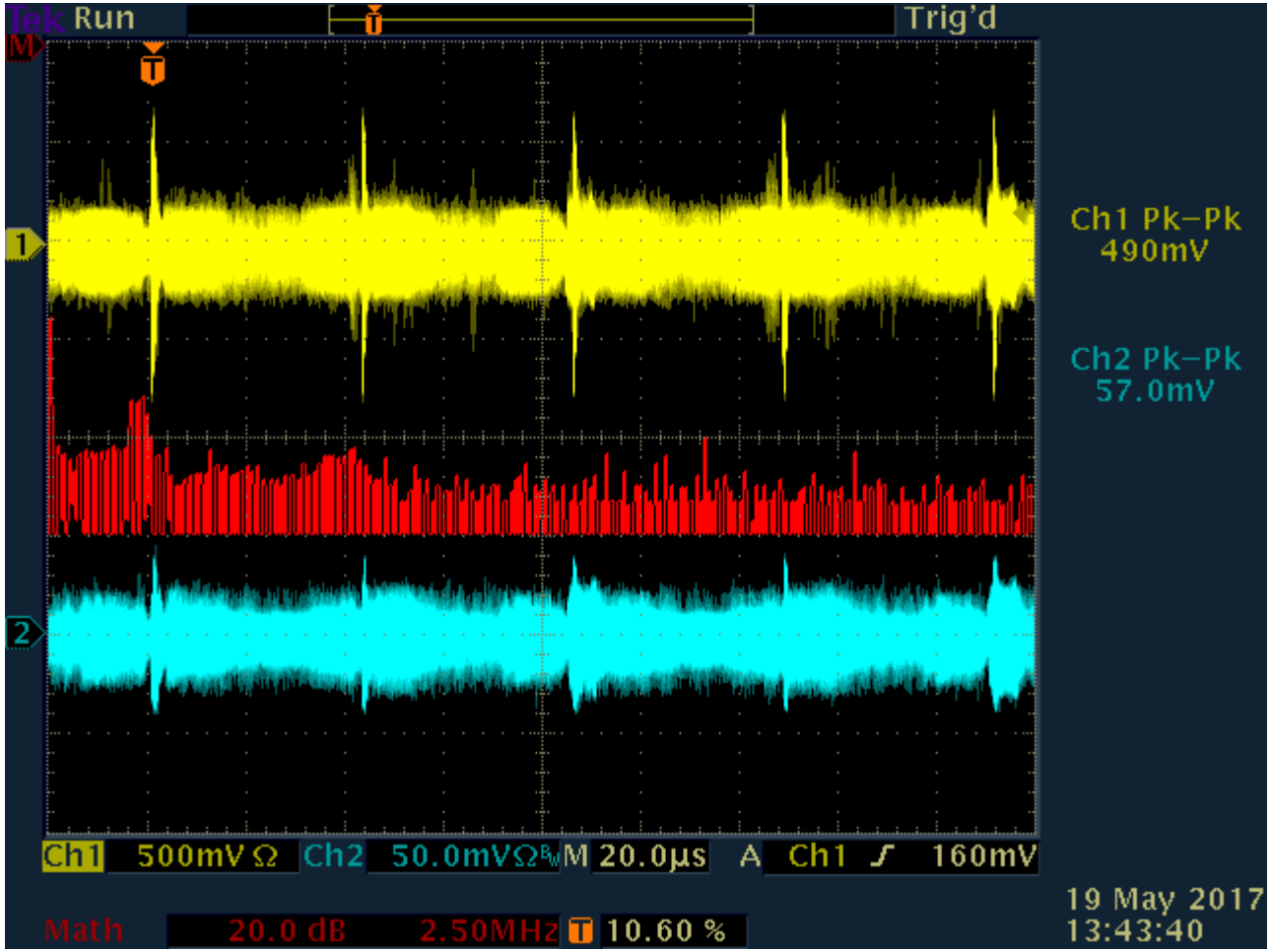


Setup: Adjacent cables, GND BALUN at Drive, 0 Hz
Measurements: Motor end



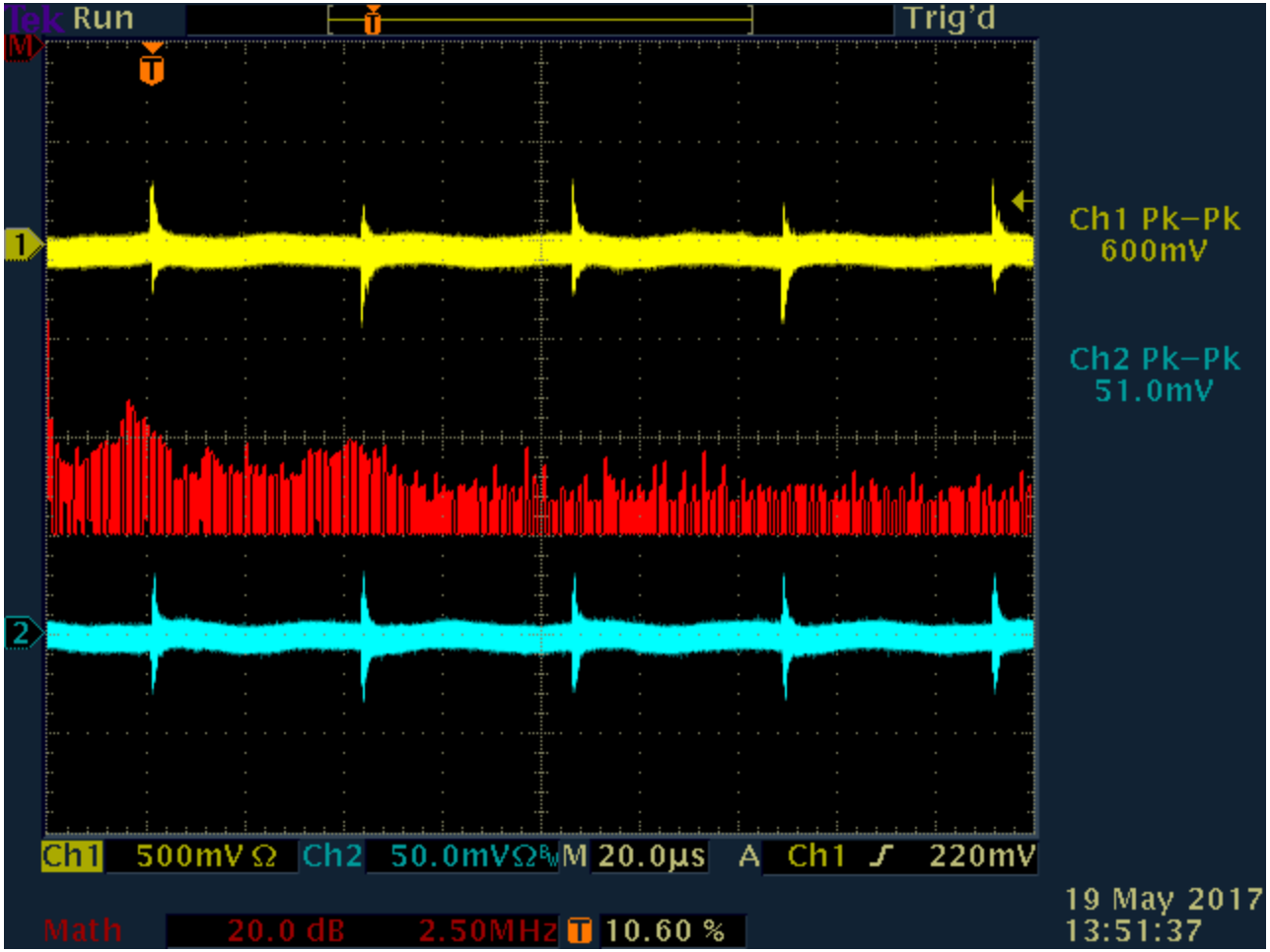
- Drive GND appears to add little Pk noise
- ~20x voltage reduction

Setup: Adjacent cables, GND BALUN at Drive, 60 Hz
Measurements: Motor end



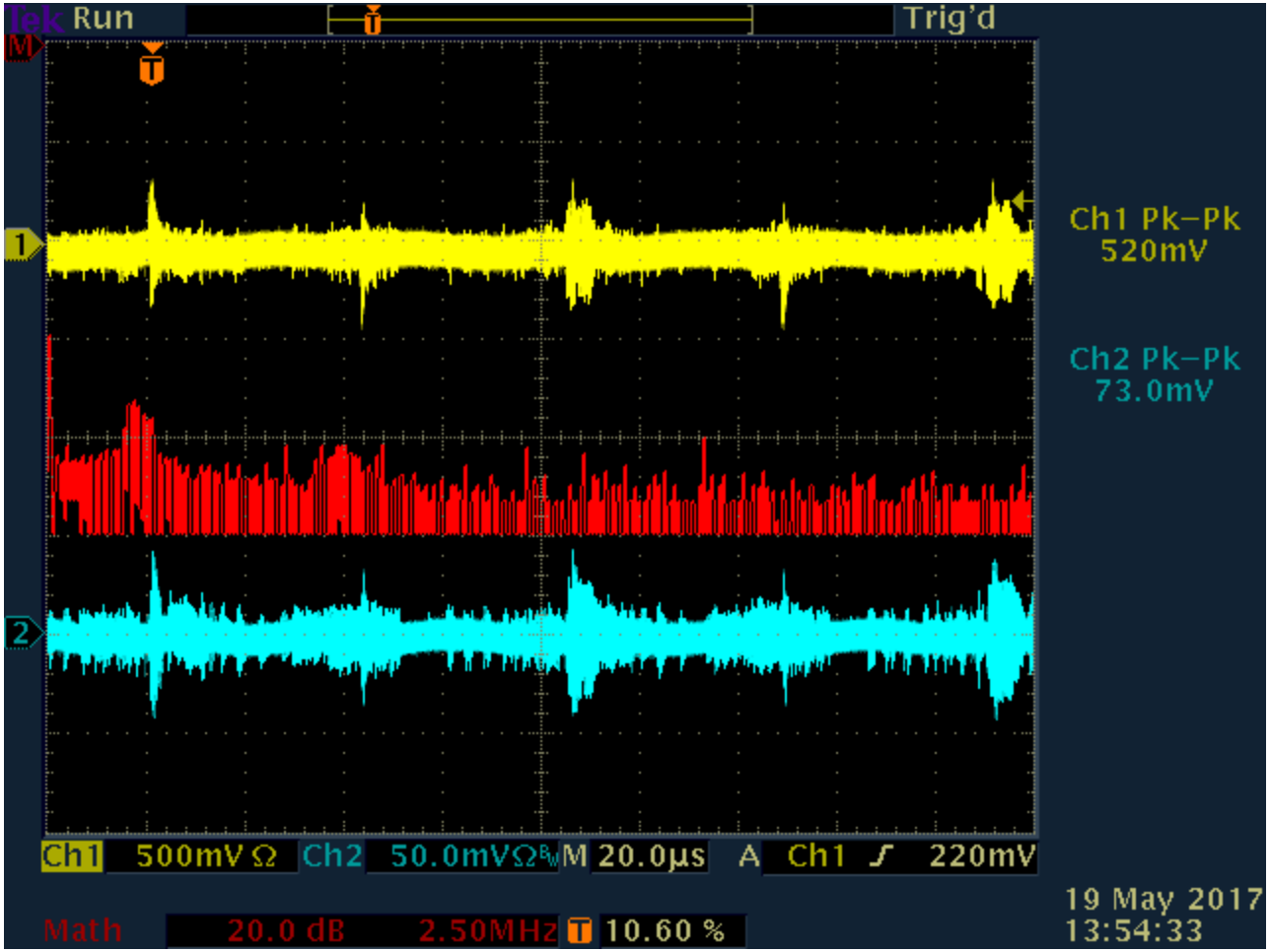
Testing with 20 cm cable separation

Setup: 20 cm cable separation, GND BALUN at Drive, 0 Hz
Measurements: Motor end



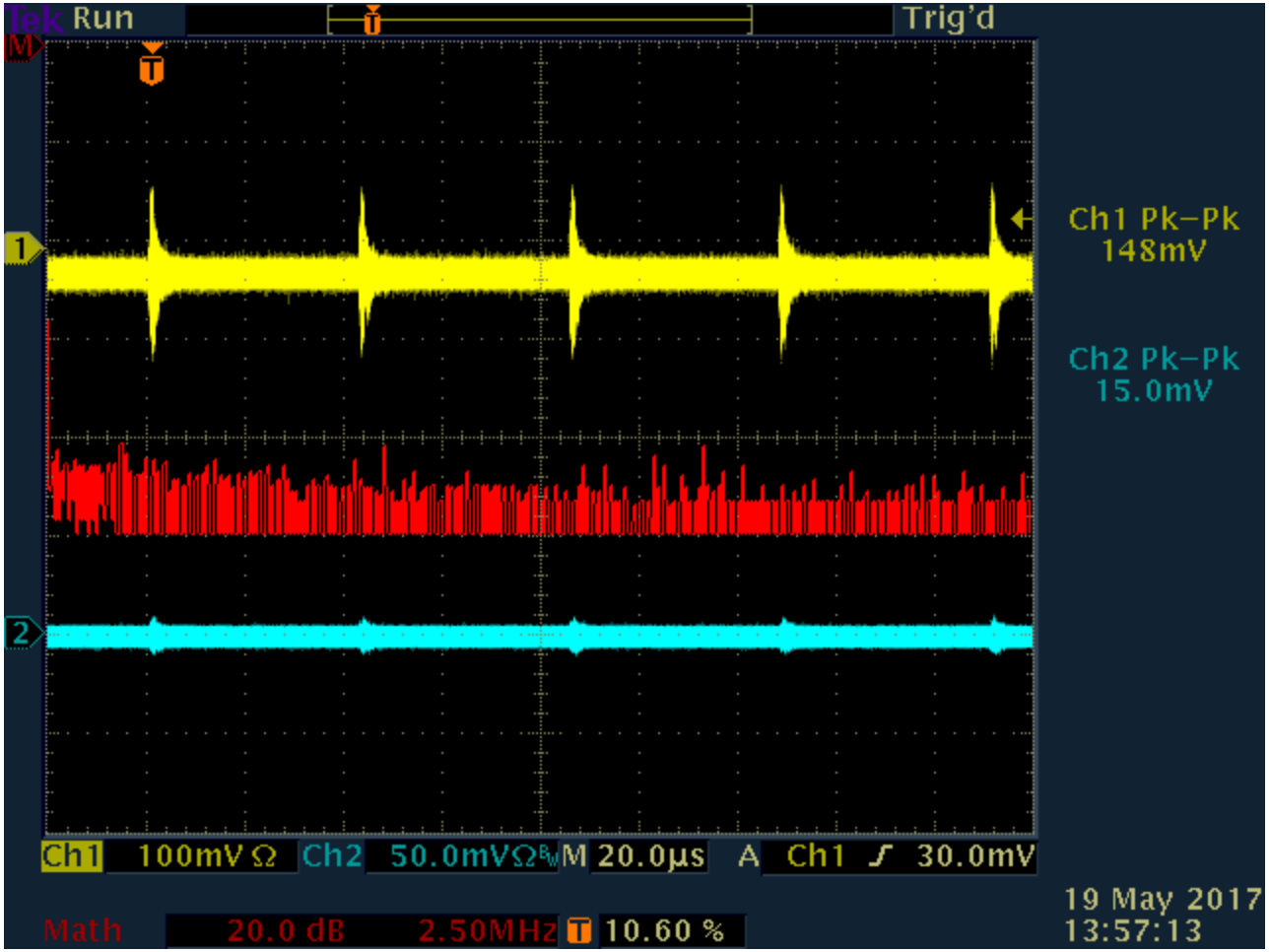
- ~10x voltage reduction
- Cable separation reduces Pk noise
- Visually appears to be 60 mV Pk-Pk

Setup: 20 cm cable separation, GND BALUN at Drive, 60 Hz
Measurements: Motor end



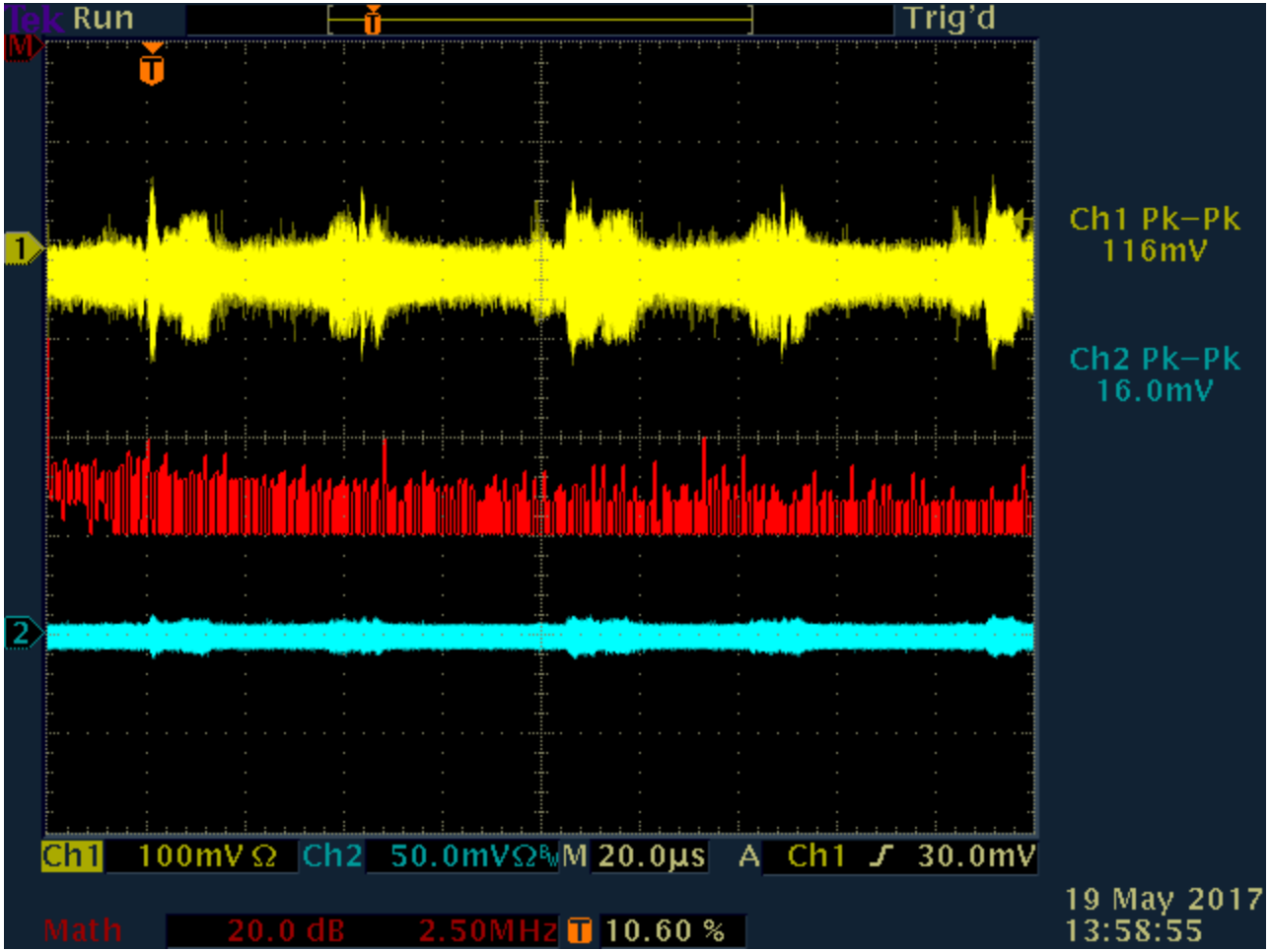
- Visually appears to be 90 mV Pk-Pk

Setup: 20 cm cable separation, Isolated GNDs, 0 Hz
Measurements: Motor end



- GND coupling was dominating over capacitive coupling between cables
- Visually appears to be 20 mV Pk-Pk

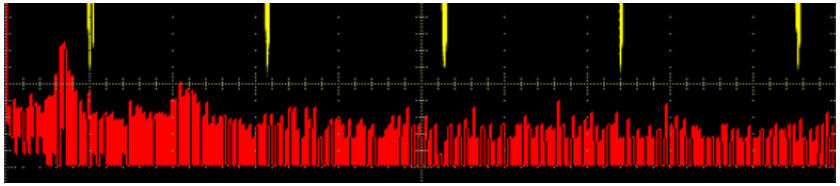
Setup: 20 cm cable separation, Isolated GNDs, 60 Hz
Measurements: Motor end



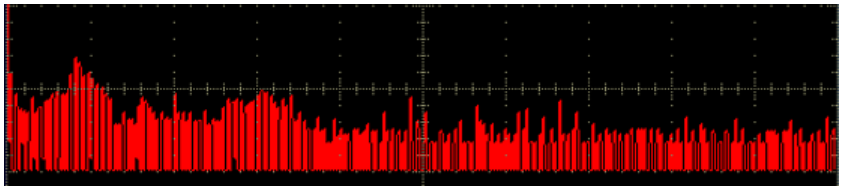
- Visually appears to be 25 mV Pk-Pk

FFT comparisons (partial)

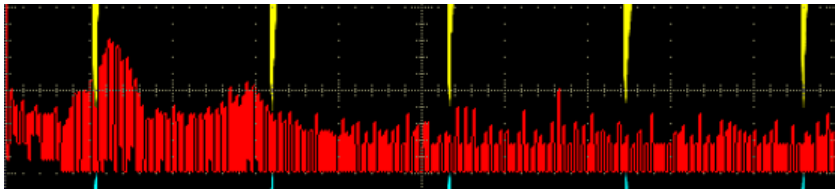
Adjacent cables, Isolated GND



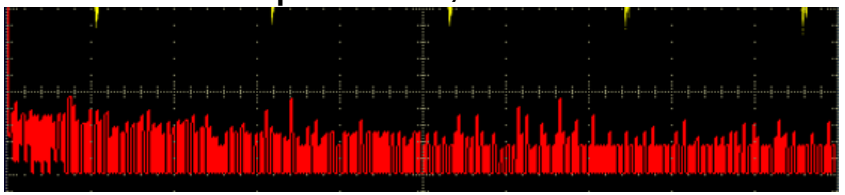
20 cm separation, Drive GND



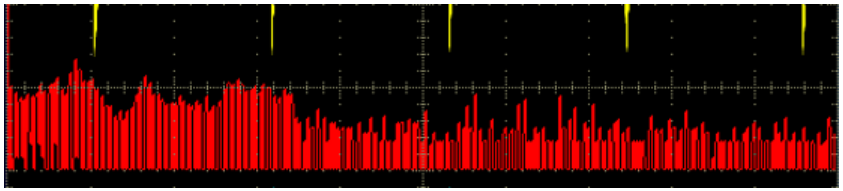
Adjacent cables, Motor GND



20 cm separation, Isolated GND



Adjacent cables, Drive GND



- Noise below 10 MHz
- Noise may come through capacitive coupling or shield grounding

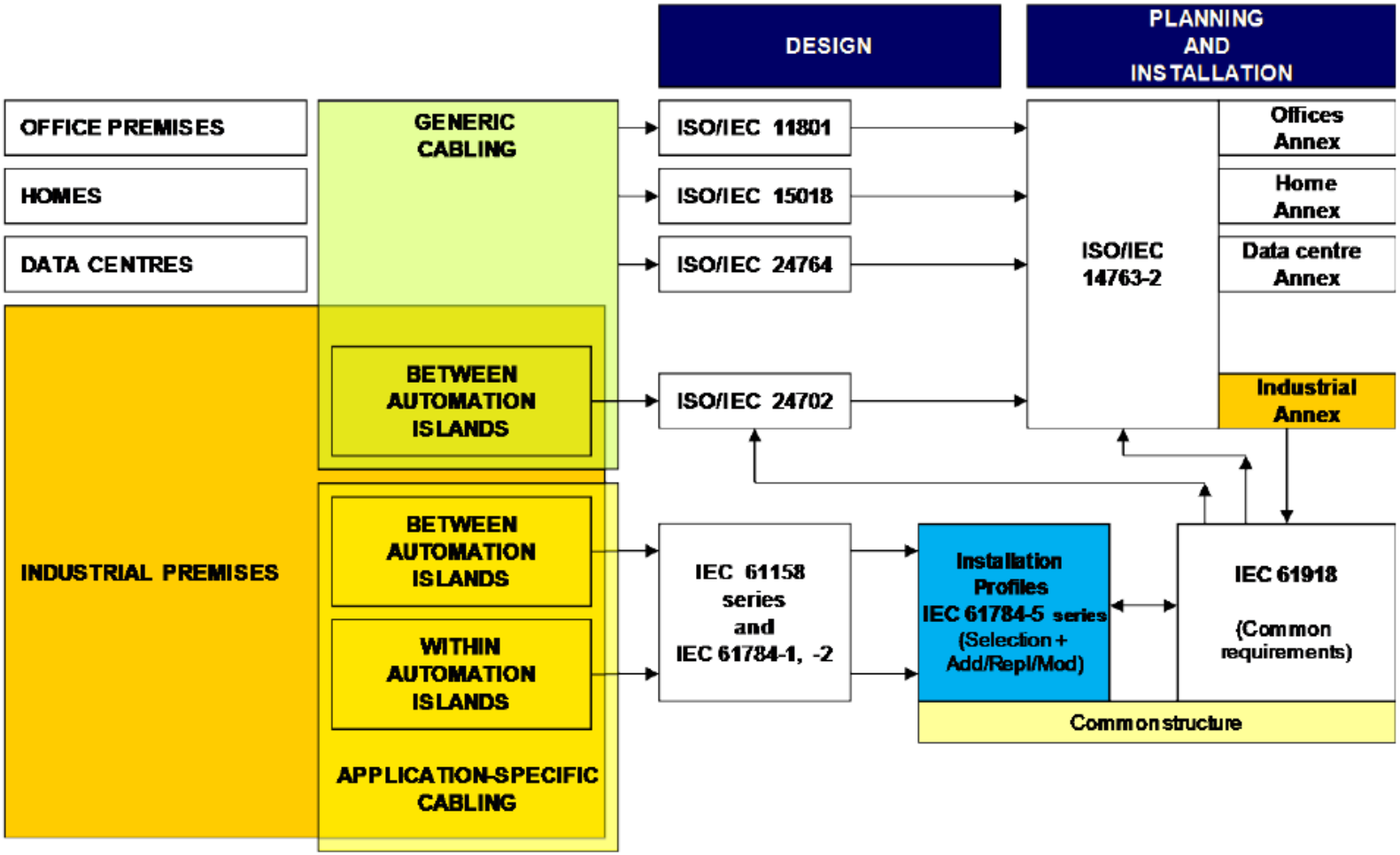
Rise time “rule of thumb”

- BW (GHz) = 0.35 / Rise_Time (ns)
- IGBT (typical)
  - Rise = 30 ns
    - BW = 11.6 MHz
  - Fall = 70 ns
    - BW = 5 MHz

Conclusions

- Drive noise can enter differential pair:
  - By capacitive coupling of parallel cables
  - Through shield sharing common GND with Drive
- Both causes must be addressed to limit noise
- Peak noise relates to 2x the PWM frequency
- A lower level of noise *appears* continuous
- Good installation practice *may* reduce noise well below the 75 mV fieldbus rule of thumb
  - This is just <u>one</u> configuration

ISO/IEC Installation standards



Installation practice – common requirements

- IEC 61918, Edition 3, 2013
  - "Industrial communication networks – Installation of communication networks in industrial premises"
    - Basic requirements for installation of media for communication networks in industrial premises within and between the automation islands
    - Covers balanced cabling
- Versions since 2007

IEC 61918 – Cable separation

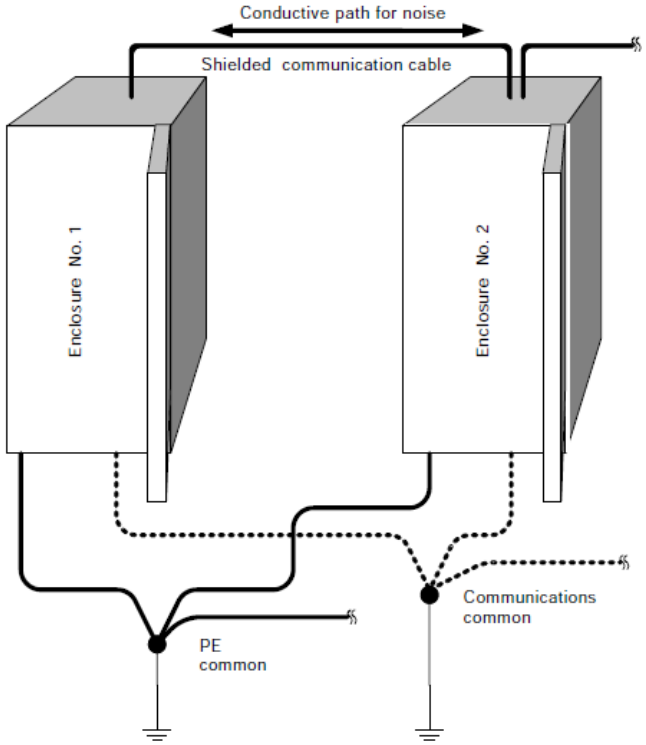
- Table of distances between communication cables and other types of circuits

Table 17 – Cable circuit types and minimum distances

Circuit type	Cables for	Distance for routing outside enclosure	Distance for routing inside enclosure or metallic pathway
AC power lines of greater than 100 kVA High-power digital a.c. I/O High-power digital d.c. I/O Power connections (conductors) from motion drives to motors	Motors Motor drives Secondary spark welders, power mains	0,6 m (24 in)	0,3 m (12 in)

IEC 61918 – Shield earthing

- 5.7.4 Shield earthing methods
  - Generic description of RC and direct connection options
- 5.7.5 Specific requirements for CPs
  - “Additional information regarding the earthing and shielding installation requirements for a specific industrial network may be found in the respective installation profile.”
- 4.4.7.3.2 Star
  - “Currents in earth paths generated by high currents can be controlled by the means of a star earthing system and by isolating the signal earth from the equipment earth.”



IEC 61784-5-1 (one of several)

- Industrial communication networks – Profiles – Part 5-1: Installation of fieldbuses – Installation profiles for CPF 1
  - CPF 1 = FOUNDATION™ Fieldbus
  - Requirements are in IEC 61918:2013 unless amended by “supplementing, modifying, or replacing”
- No amendment to separation requirements
- A.4.4.7.5 Specific requirements for CPs
  - “For CP 1/1 four options are available to the planner for shield termination.”

Next Steps

- Some additional scrutiny on this configuration
- Characterize the communication cable
- Test with a longer run of cable
- Test with a larger Drive and Motor