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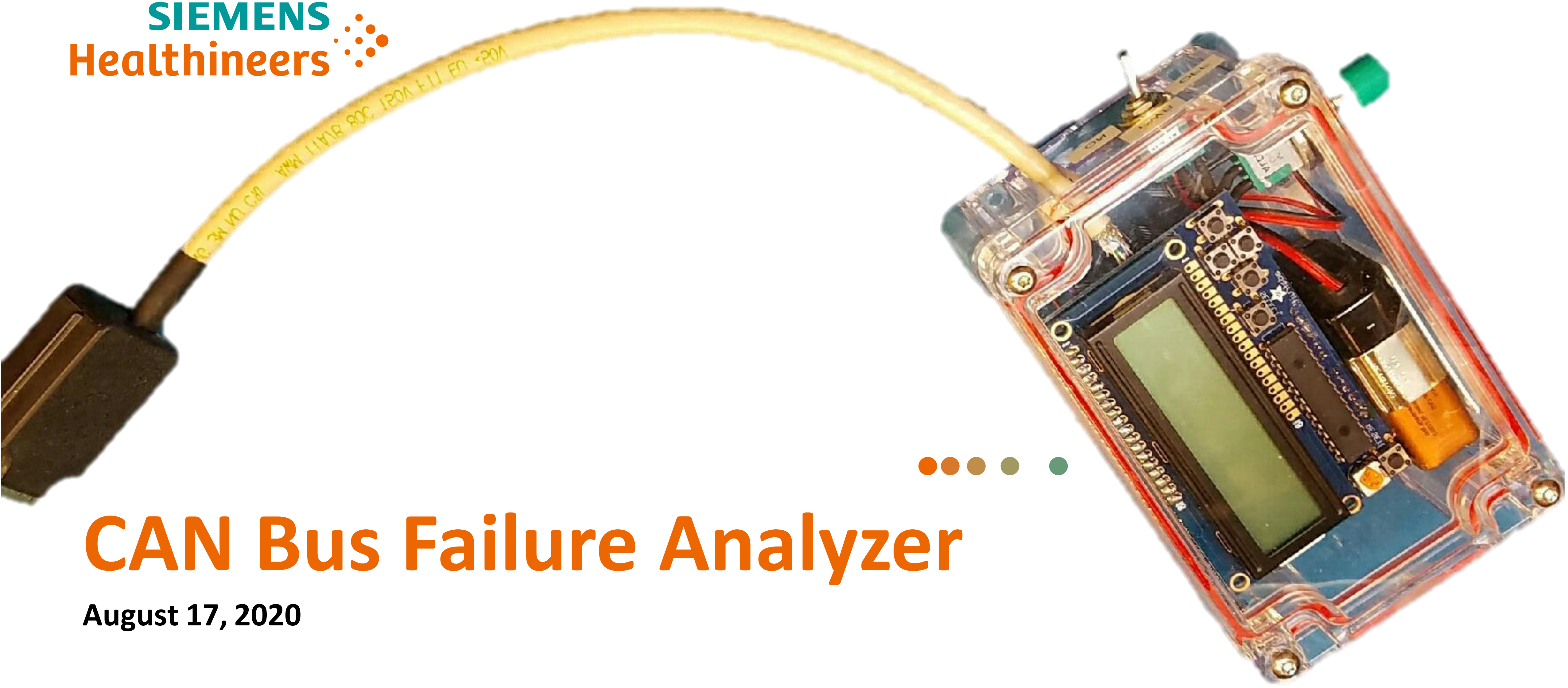


# CAN Bus Failure Analyzer

**August 17, 2020**

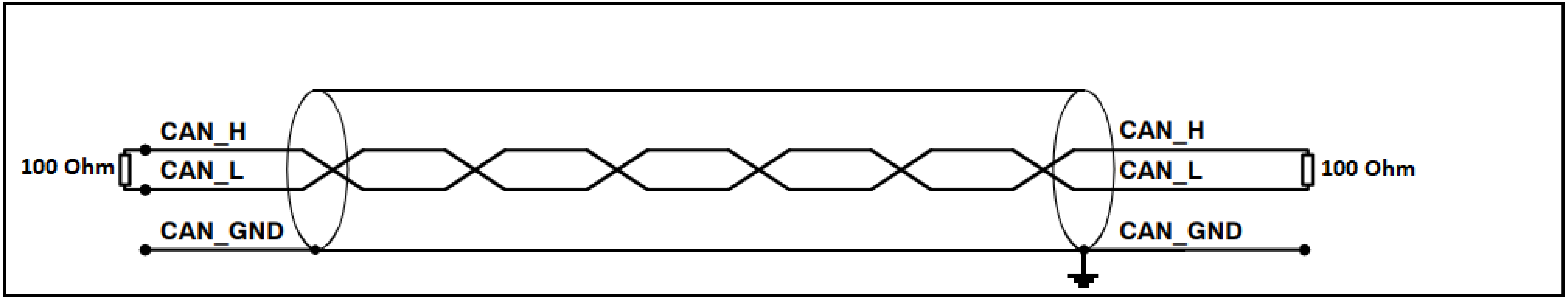
# Discussion Topics

1. Intro
2. Problem statement
3. CAN Bus architecture on Hydra
4. CAN Bus characteristics
5. Tester capabilities
6. Tester hardware architecture
7. Tester firmware
8. Demo
9. Tester cables
10. Issues encountered
11. Conclusion and next steps

# 2. Problem Statement

Due to instrument complexity, it is difficult for field engineers to troubleshoot CAN network issues on Hydra.

The CAN Bus Failure Analyzer will aid in basic testing of the network and eliminating common wiring problems.



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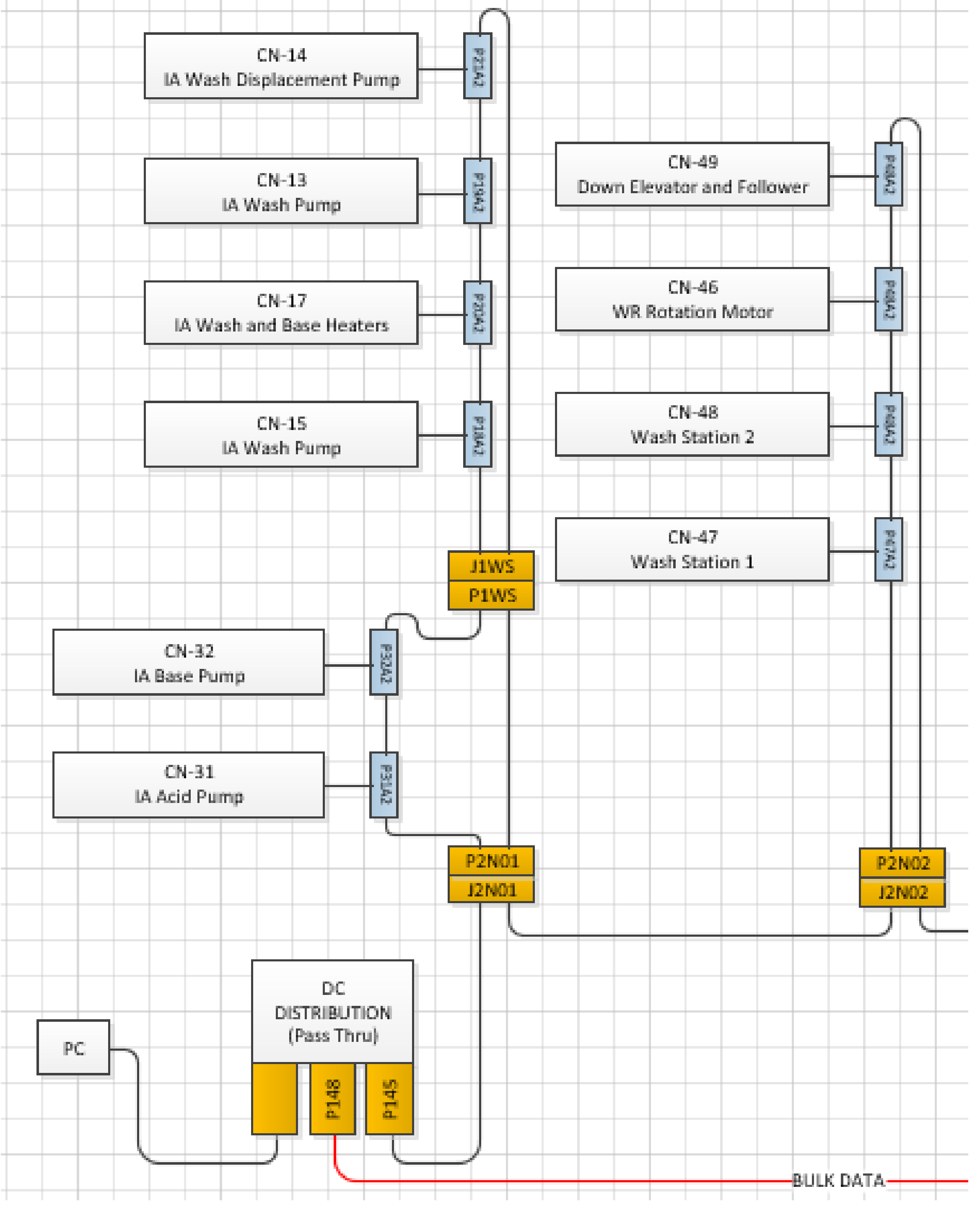
# 3. Overview of Hydra CAN Network Architecture



# 4. CAN Bus Physical Layer

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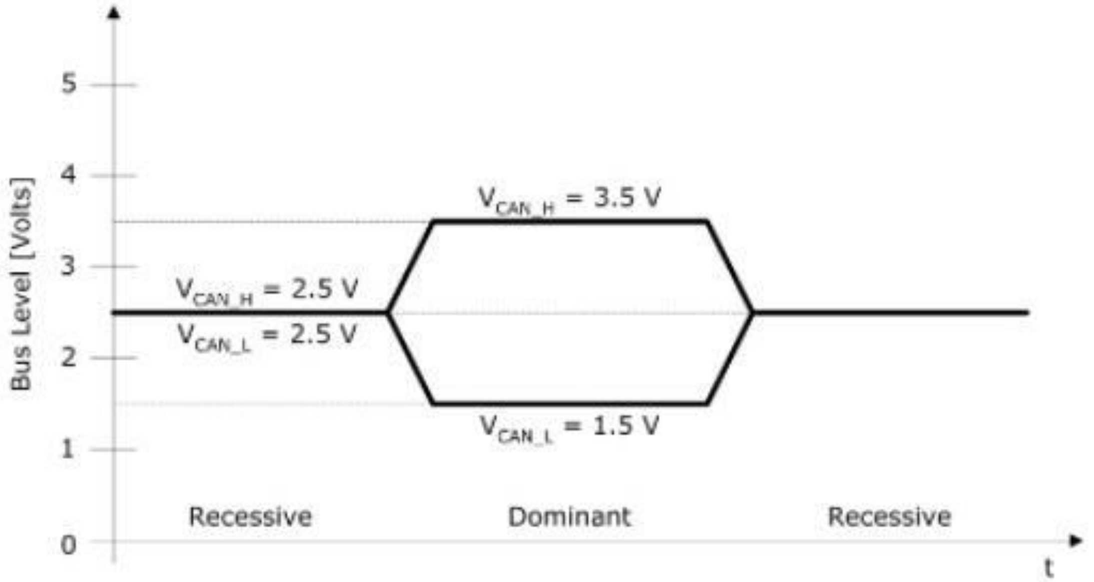
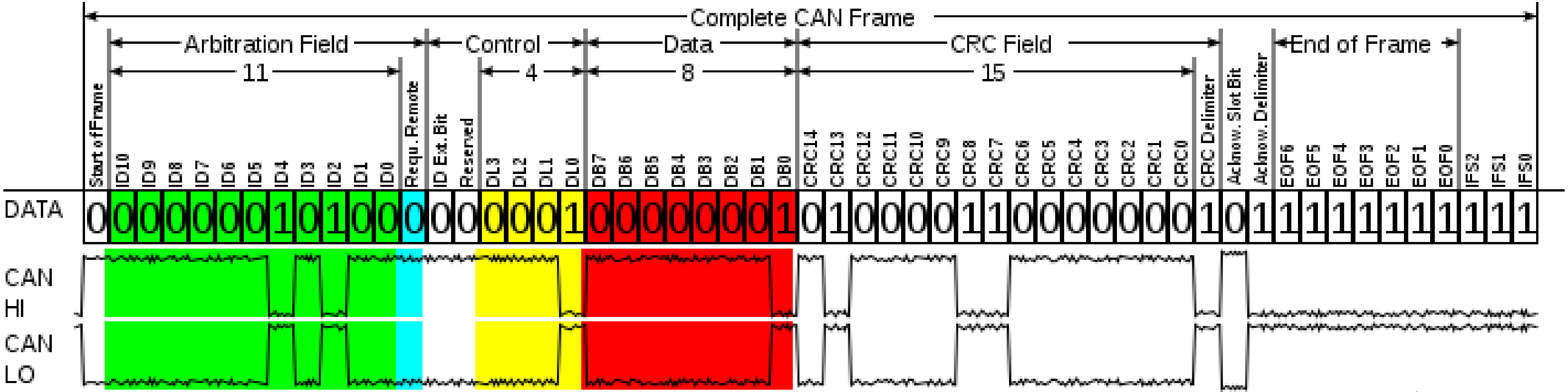
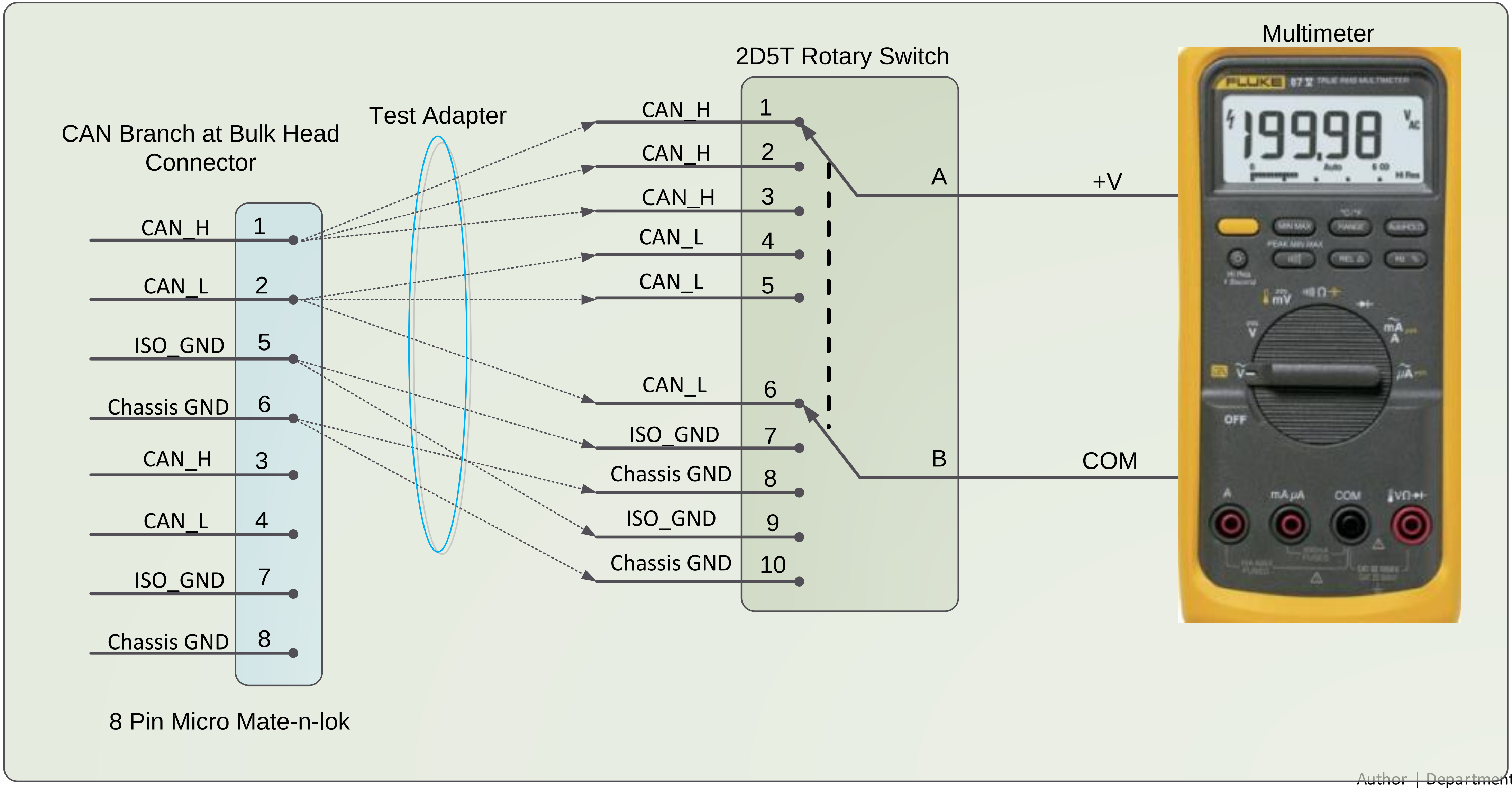


# 5. Tester Capabilities



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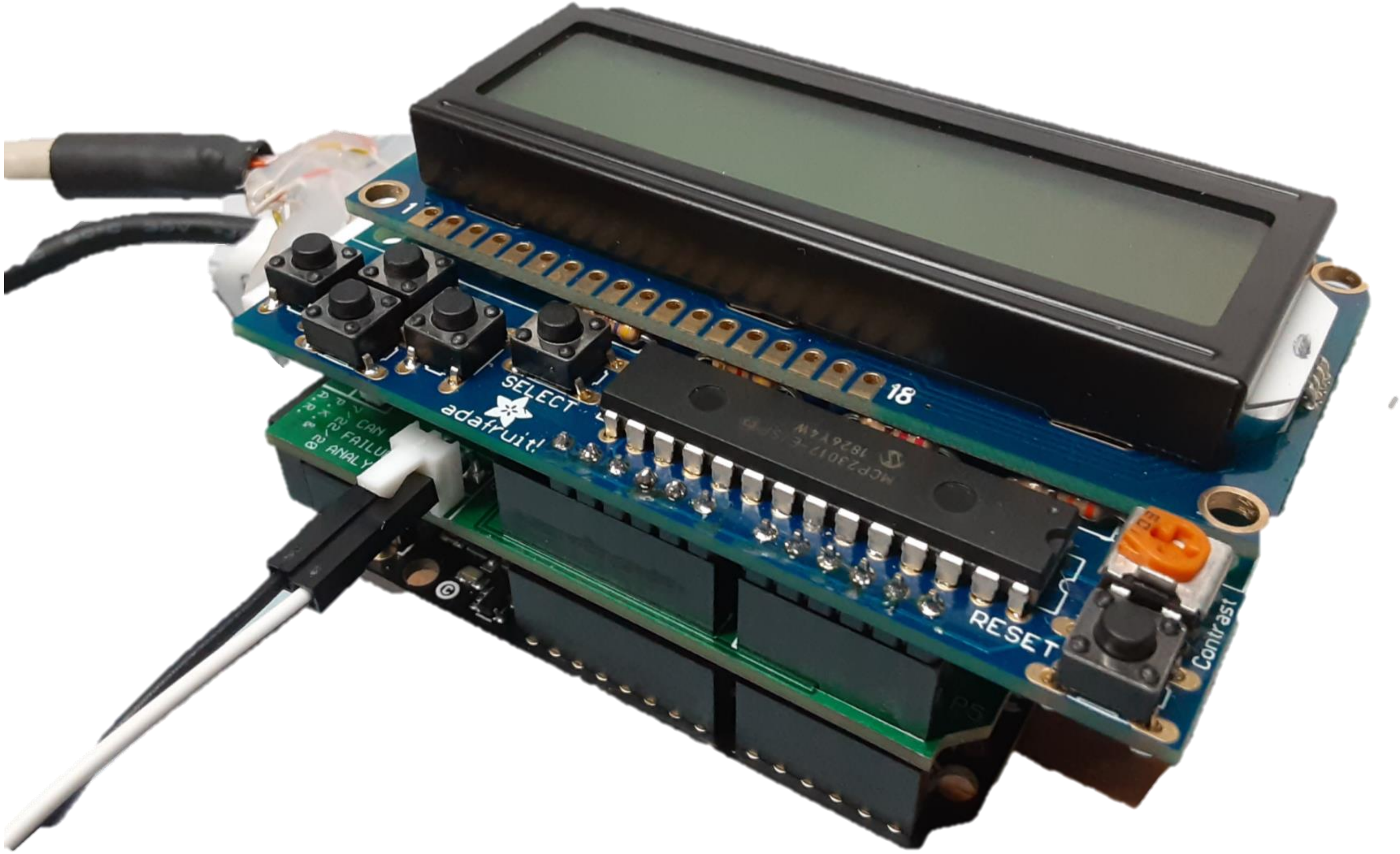
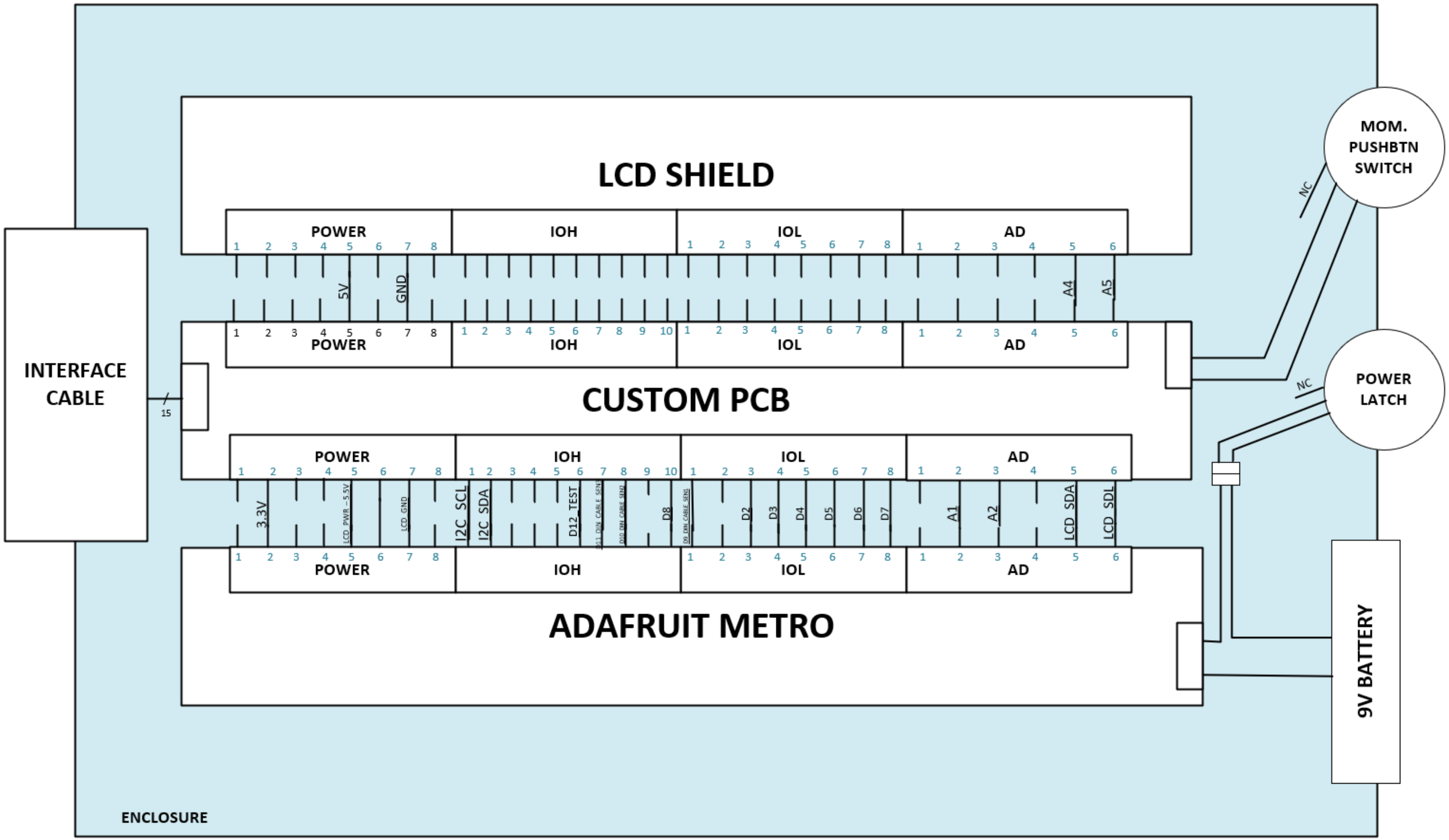
# 6. Tester Hardware Architecture

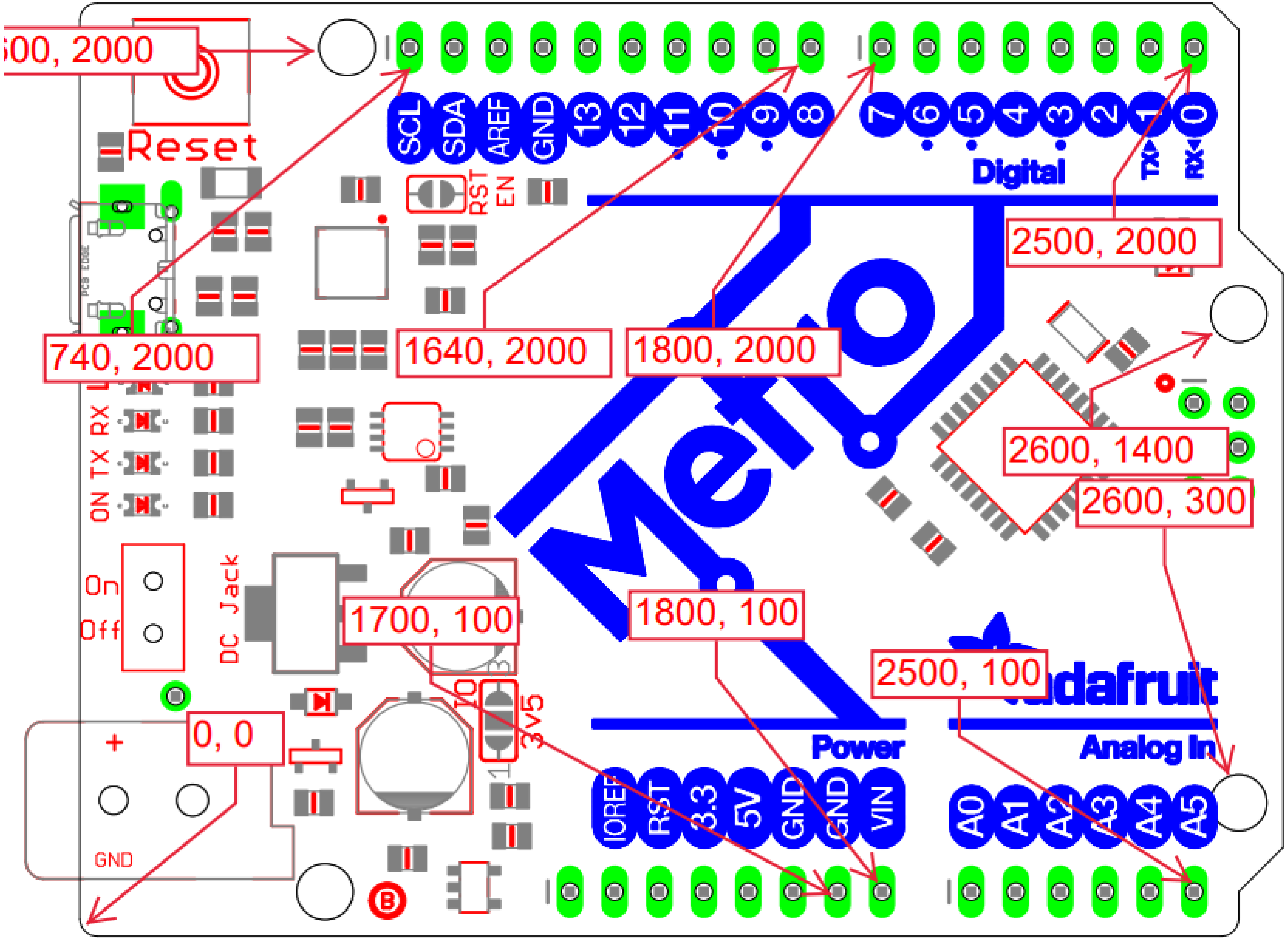


# Board Stack

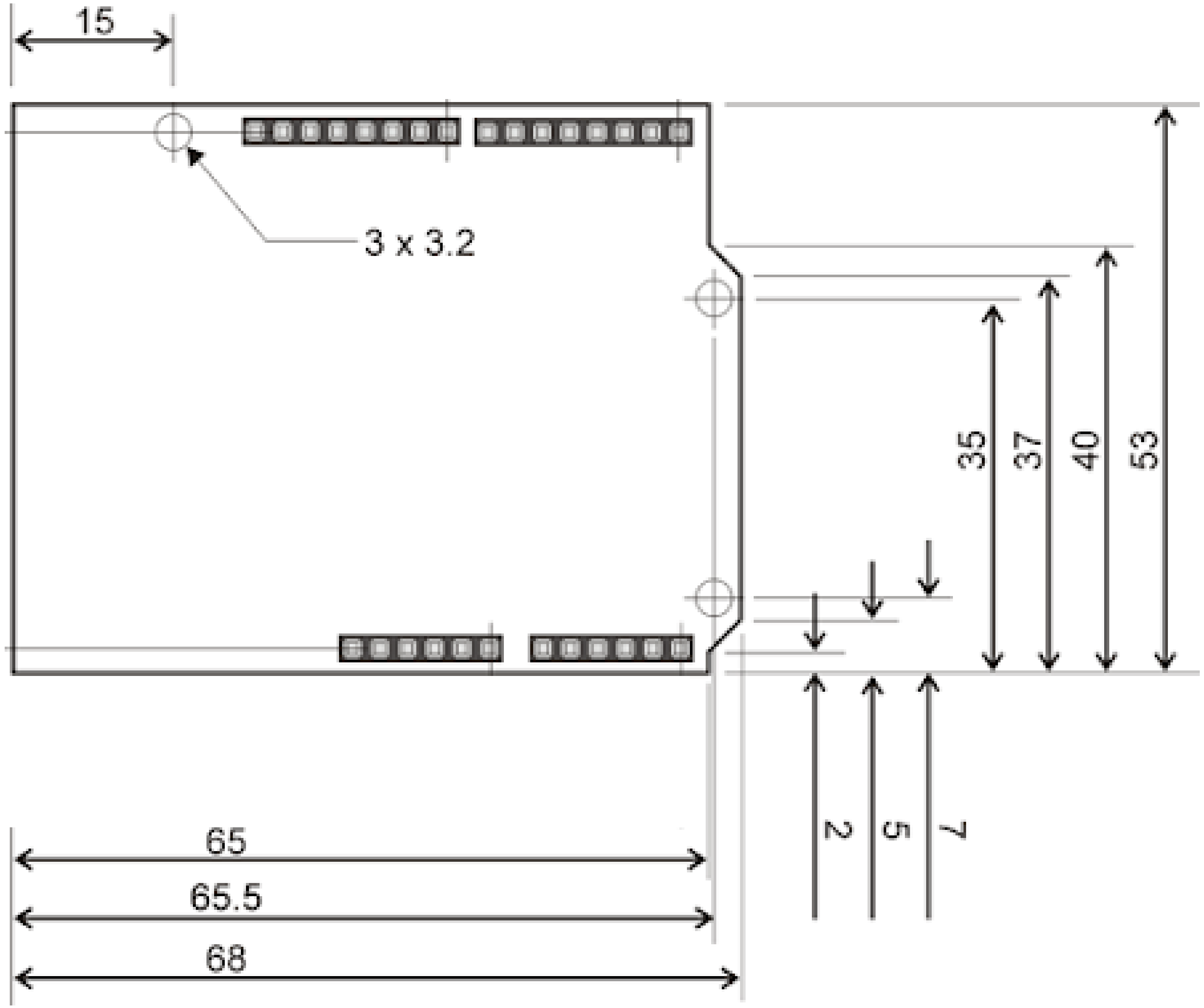


LCD SHIELD
POWER
IOH
IOL
AD
5V
GND
A4
A5
CUSTOM PCB
INTERFACE CABLE
15
3.3V
LCD PWR ~5.5V
LCD GND
I2C SCL
I2C SDA
D12 TEST
D8
D2
D3
D4
D5
D6
D7
A1
A2
LCD SDA
LCD SDL
ADAFRUIT METRO
MOM. PUSHBTN SWITCH
NC
POWER LATCH
9V BATTERY
ENCLOSURE

# Metro Hole Pattern

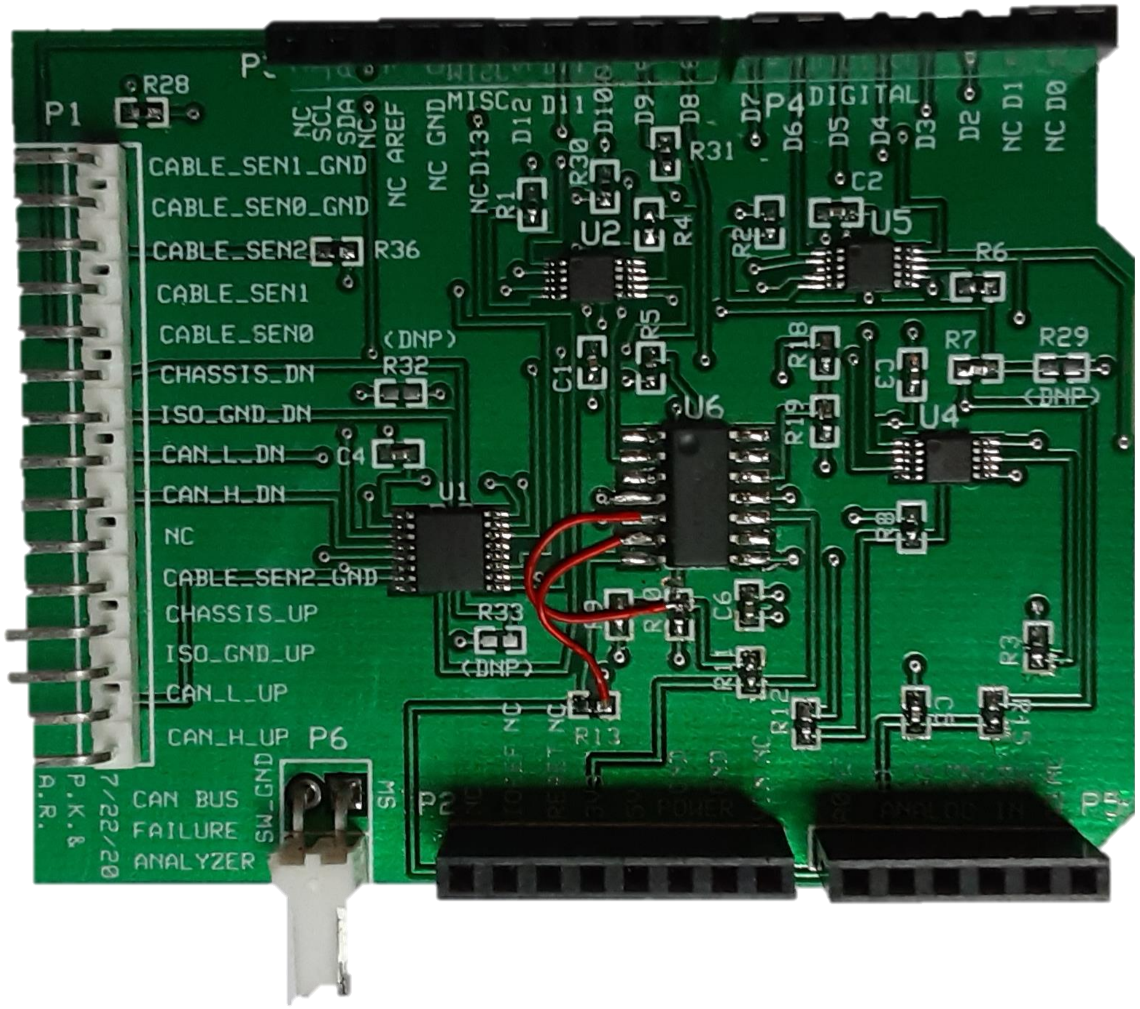


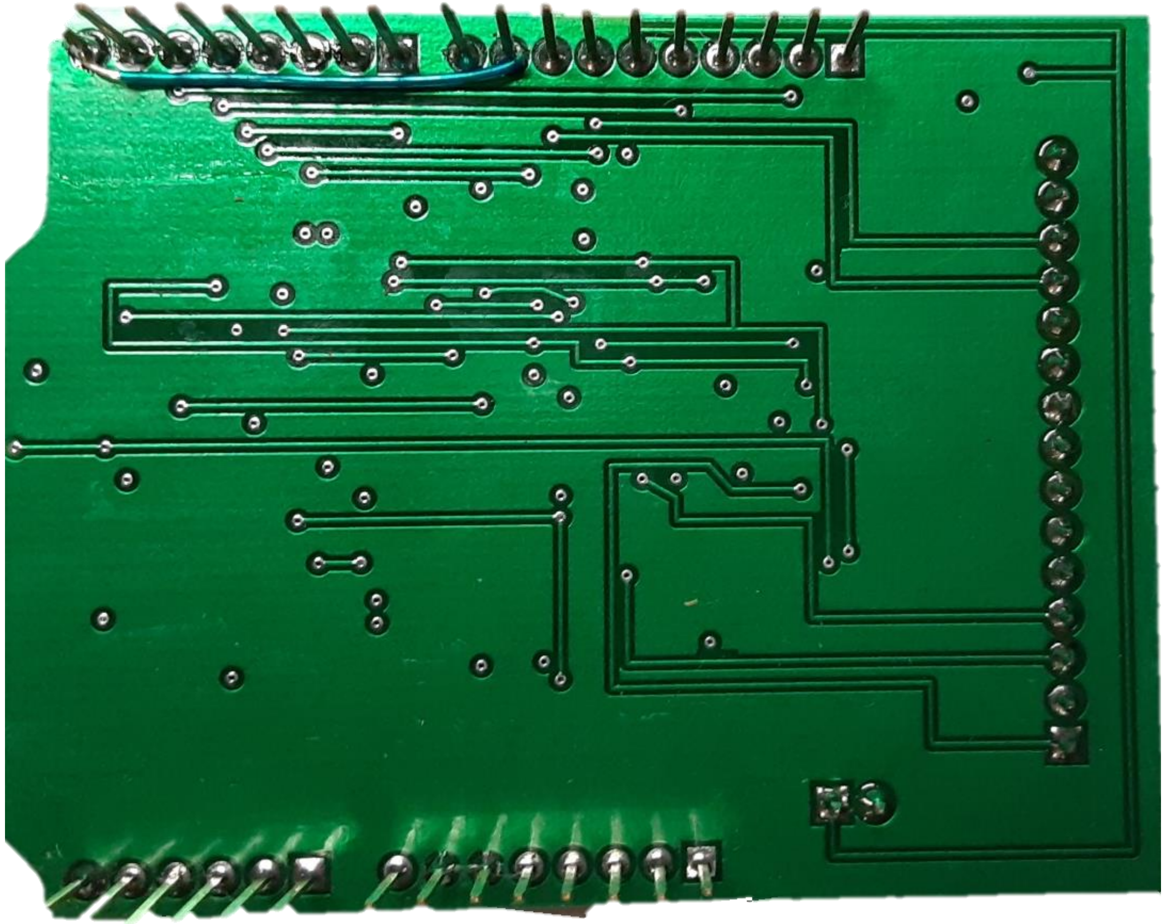
# Board Outer Dimensions



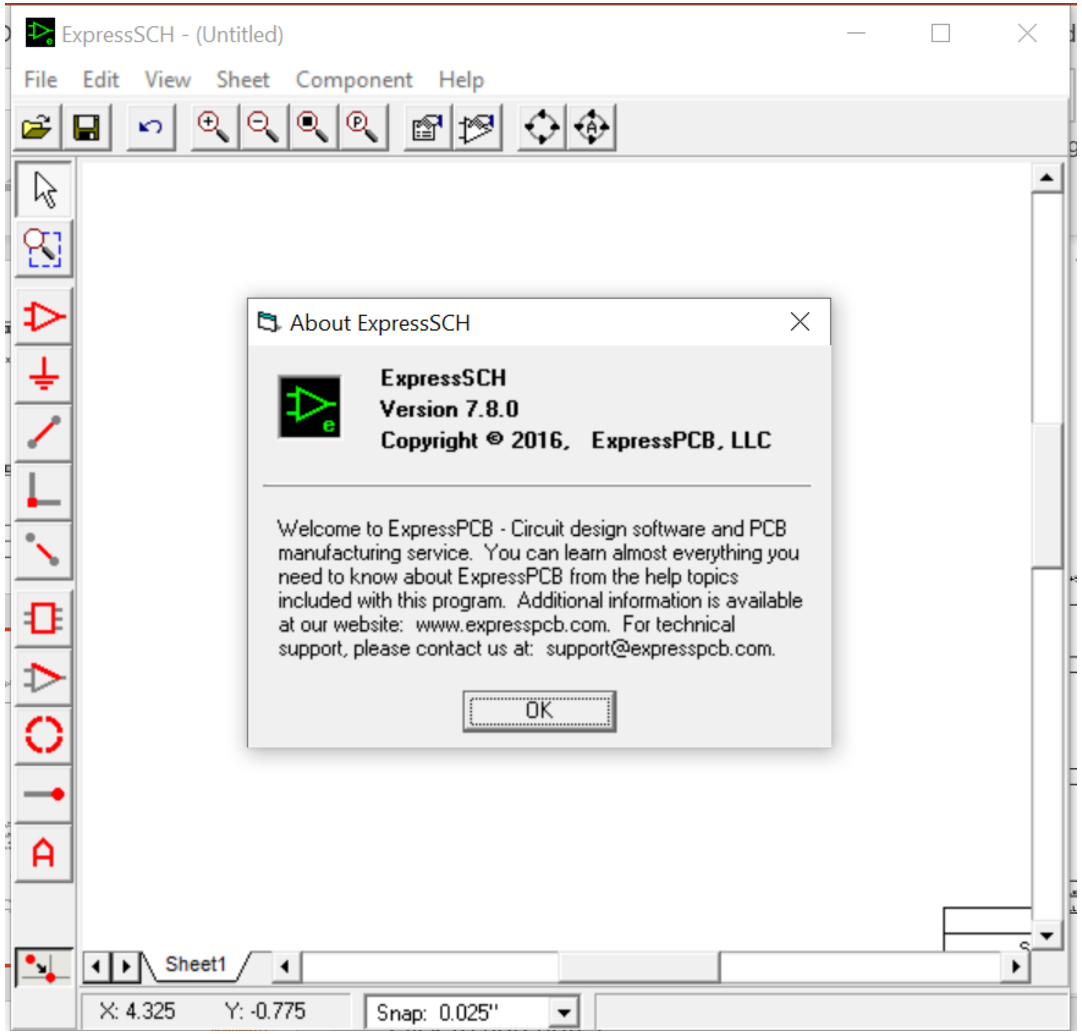
# Proto Board

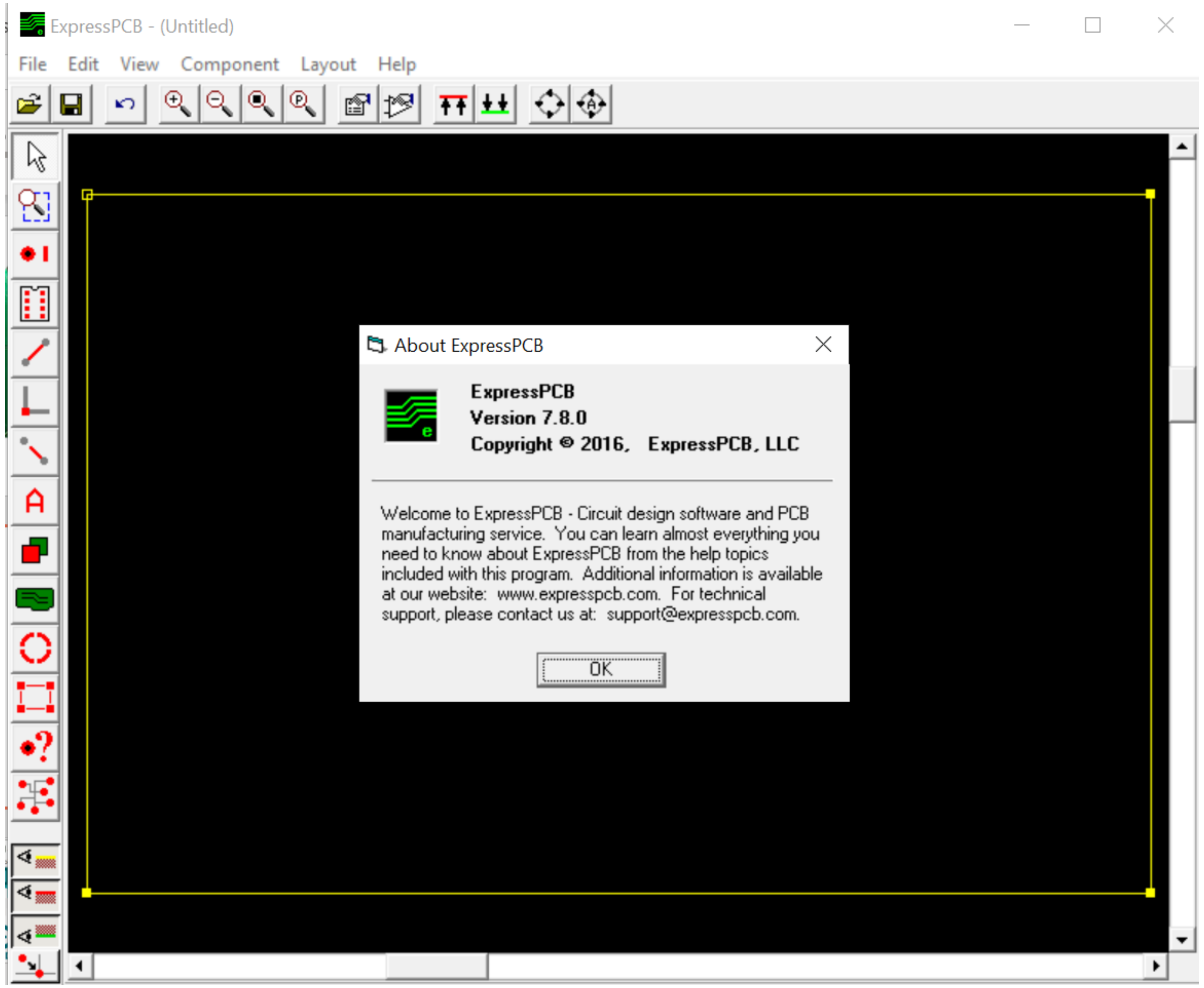



P1
R28
MISC
DIGITAL
P4
CABLE_SEN1_GND
CABLE_SEN0_GND
CABLE_SEN2
R36
CABLE_SEN1
CABLE_SEN0
(DNP)
R32
CHASSIS_DN
ISO_GND_DN
CAN_L_DN
C4
CAN_H_DN
U1
NC
CABLE_SEN2_GND
CHASSIS_UP
ISO_GND_UP
CAN_L_UP
CAN_H_UP
P6
R33
(DNP)
R13
U2
U5
U6
U4
R6
R7
R29
(DNP)
R31
C2
C1
C3
C6
R3
P2
P5
CAN BUS
FAILURE
ANALYZER
SW_GND
SW
7/22/20
P.K.&
A.R.



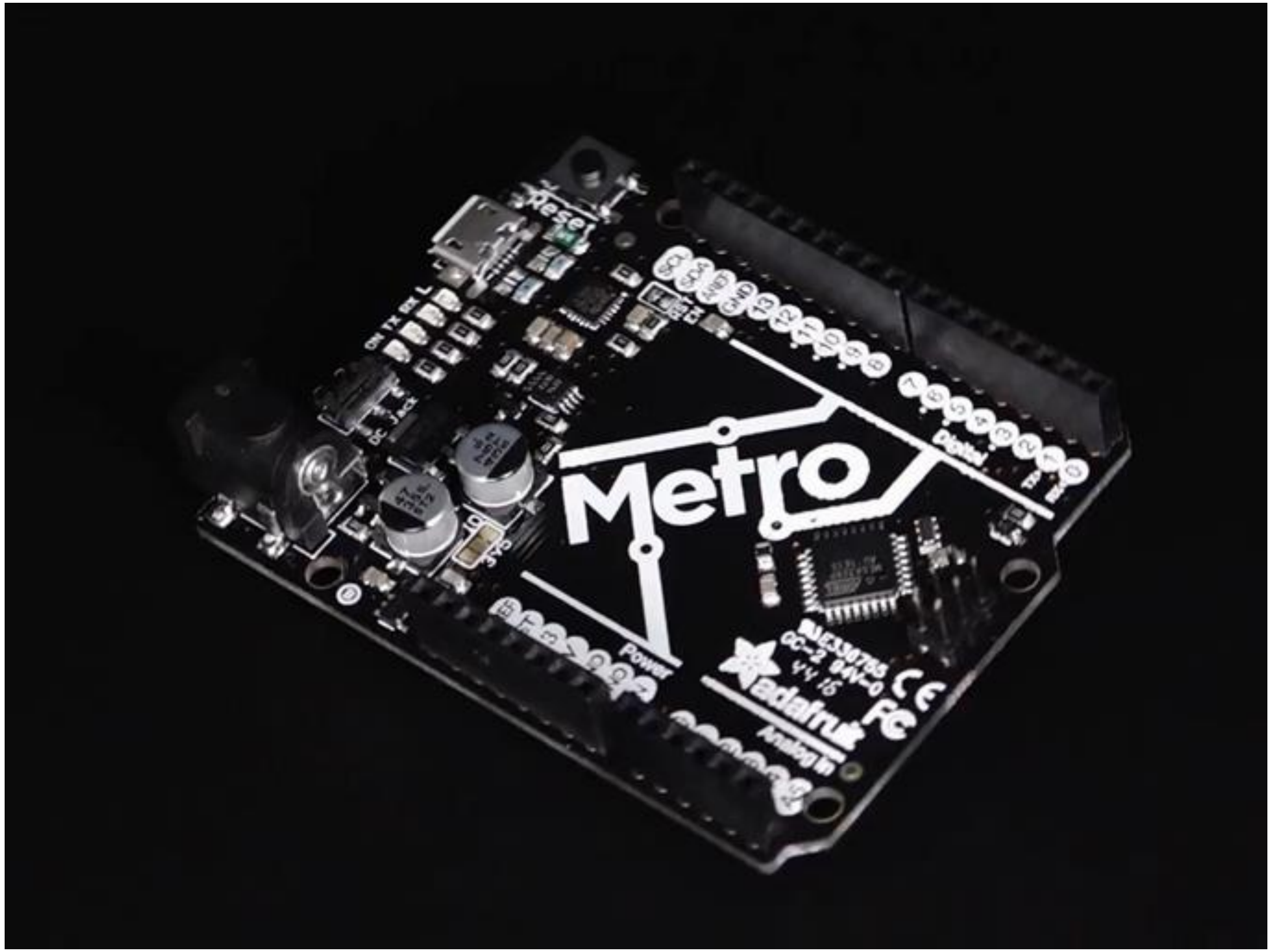
# ExpressSCH and ExpressPCB



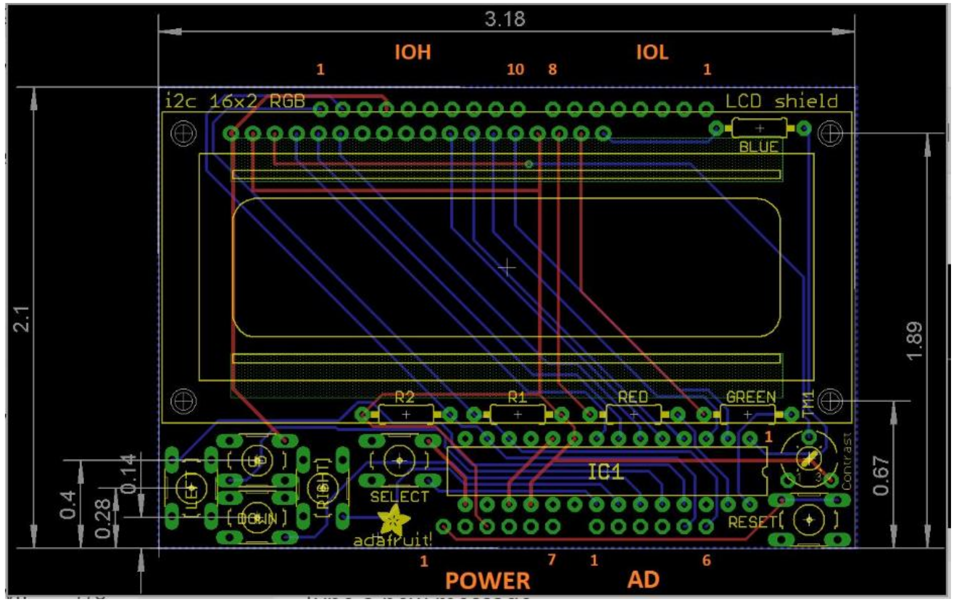
# Adafruit Metro

- Link
- Processor: ATmega 328P
- Micro is 8-bit
- 32KB flash, 2KB RAM, 16 MHz
- 20 GPIO pins of which 6 are A/D
- USB to Serial Converter
- Arduino IDE compatible



# LCD Display

- Link
- 16x2 RGB backlight LCD
- Plugs in to Arduino Classic (UNO, Duemilanove, Diecimilla and Arduino Mega R3)
- I2C Interface
- 5V logic compatible only

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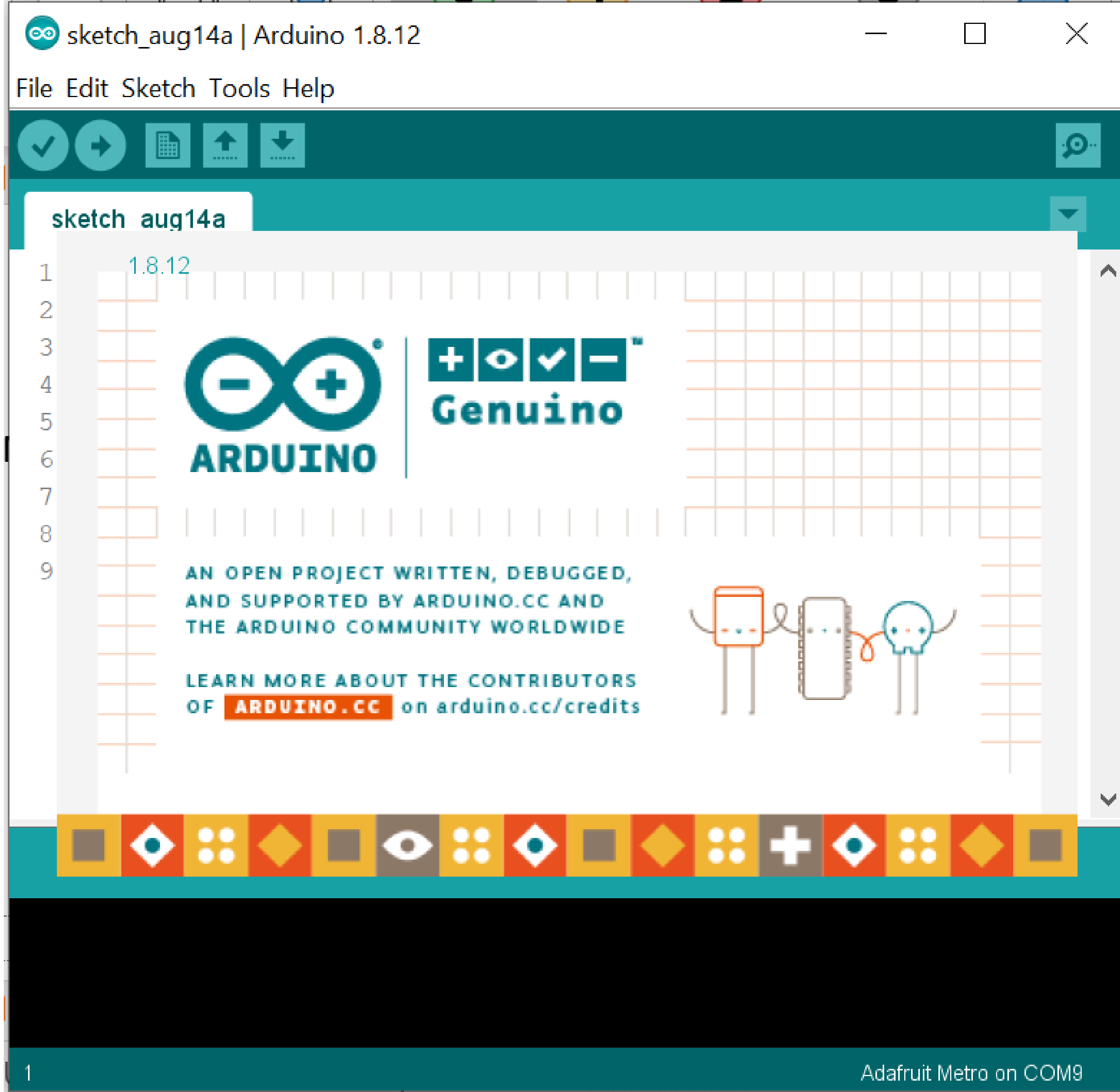
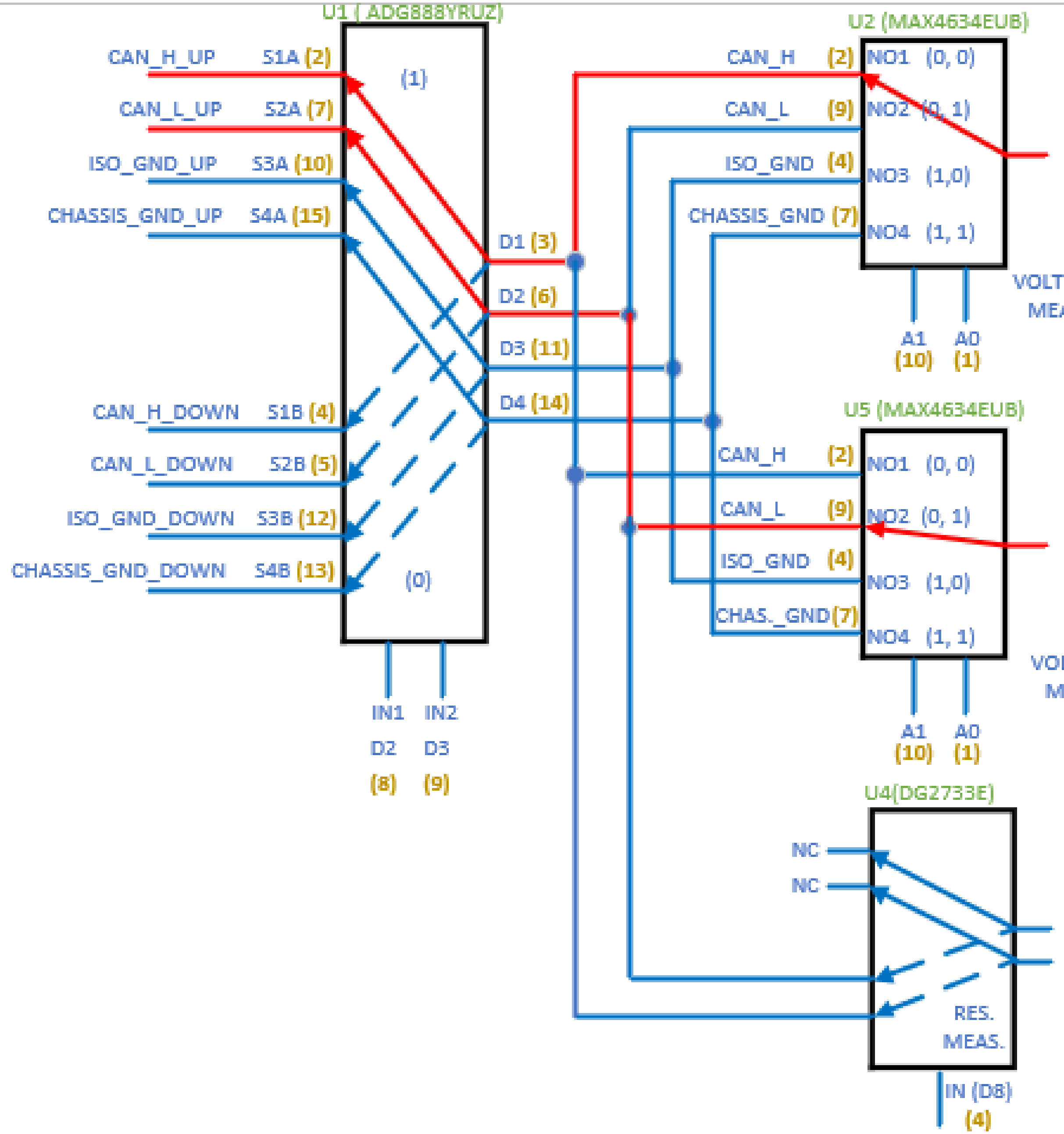
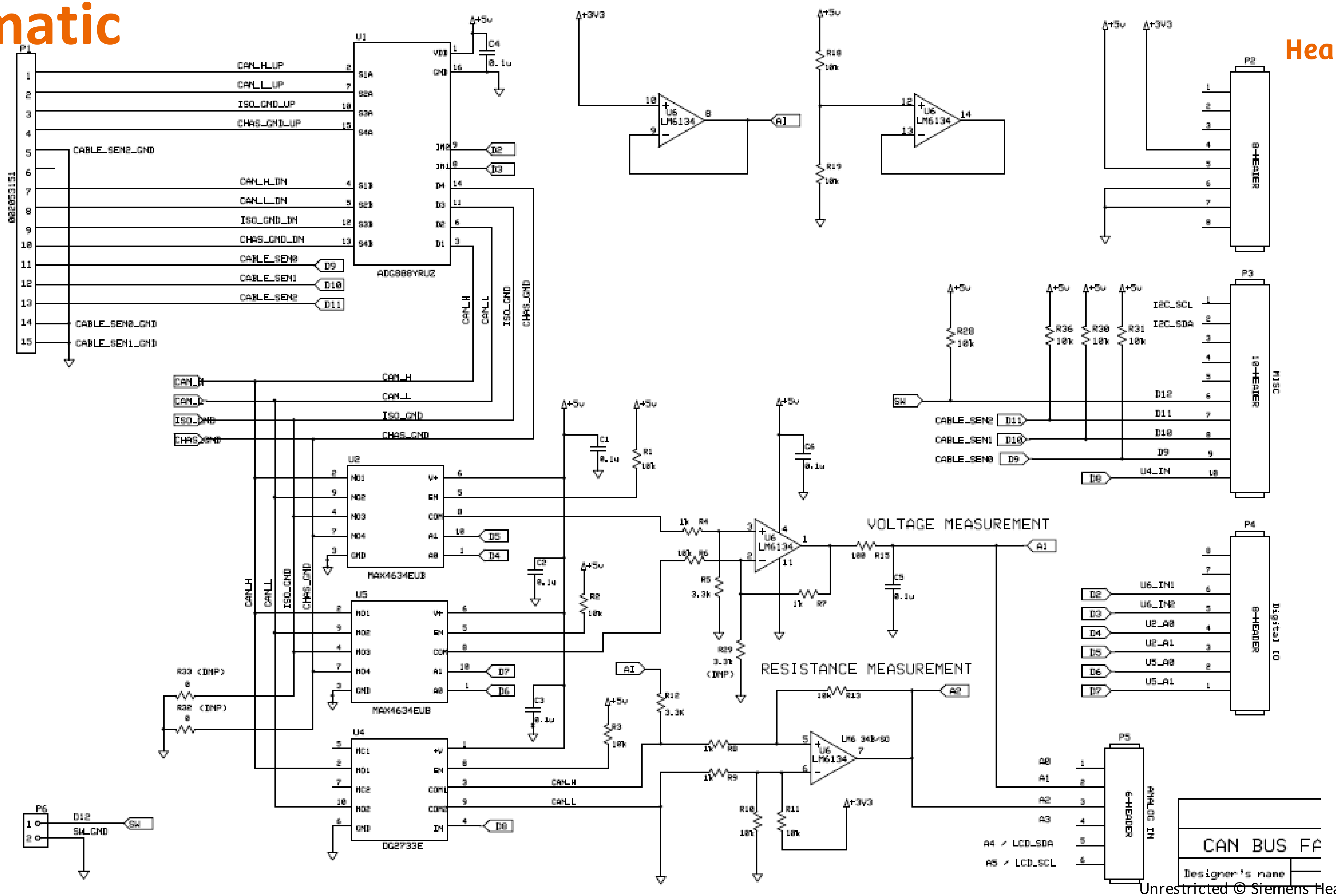
# 7. Tester Firmware



# Signal Flow Template



# Schematic

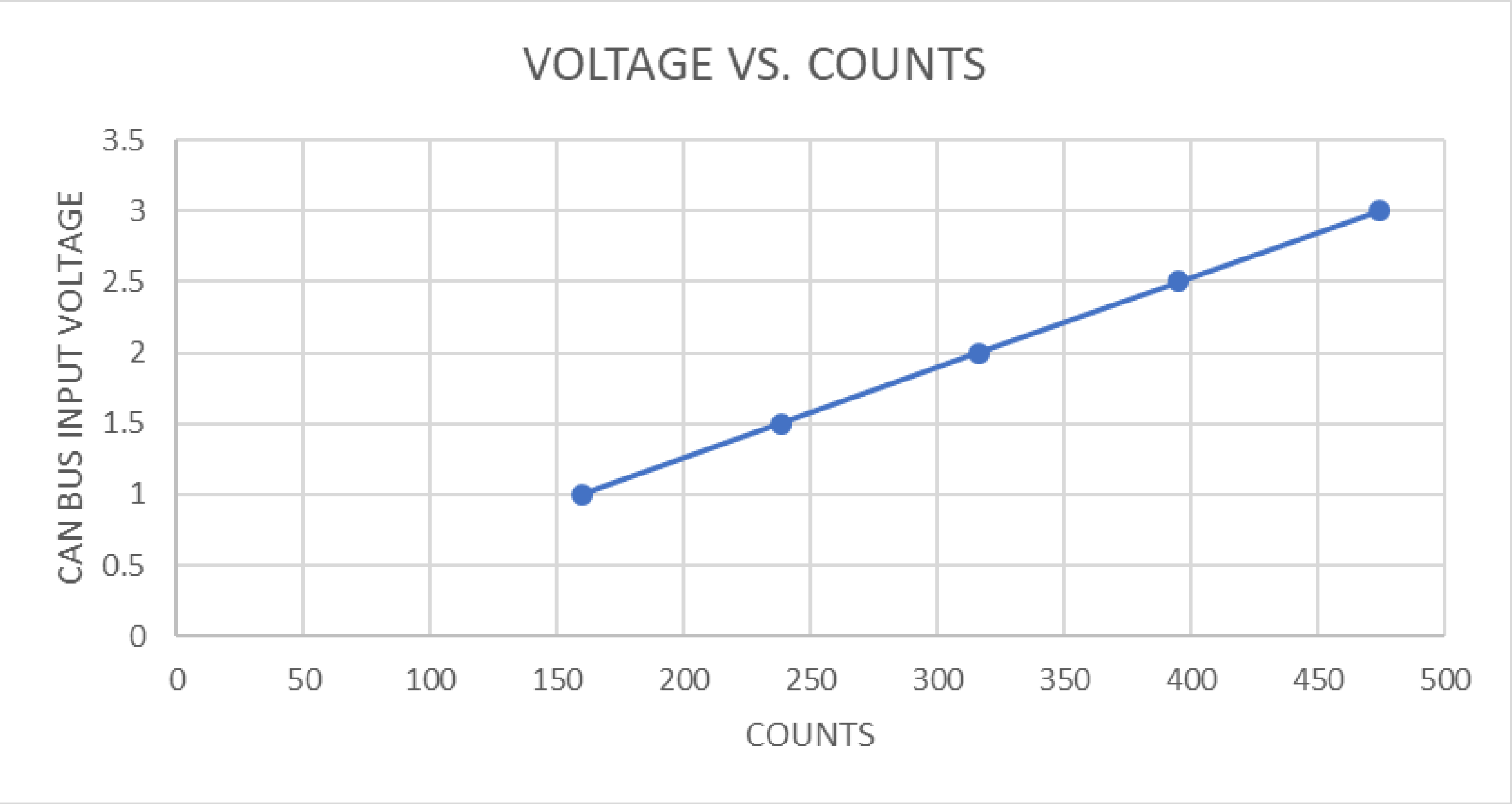


VOLTAGE MEASUREMENT
RESISTANCE MEASUREMENT
CAN BUS FA
Designer's name

# Voltage Curve Fit

| PWR SUPPLY INPUT VOLTAGE | COUNTS |
|---|---|
| 1 | 160 |
| 1.5 | 238 |
| 2 | 316 |
| 2.5 | 395 |
| 3 | 474 |

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.99999432 |
| R Square | 0.999988641 |
| Adjusted R Square | 0.999984854 |
| Standard Error | 0.003076708 |
| Observations | 5 |
| | |
| ANOVA | |
| | *df* |
| Regression | 1 |
| Residual | 3 |
| Total | 4 |
| | |
| | *Coefficients* |
| Intercept | -0.016537603 |
| X Variable 1 | 0.006369354 |

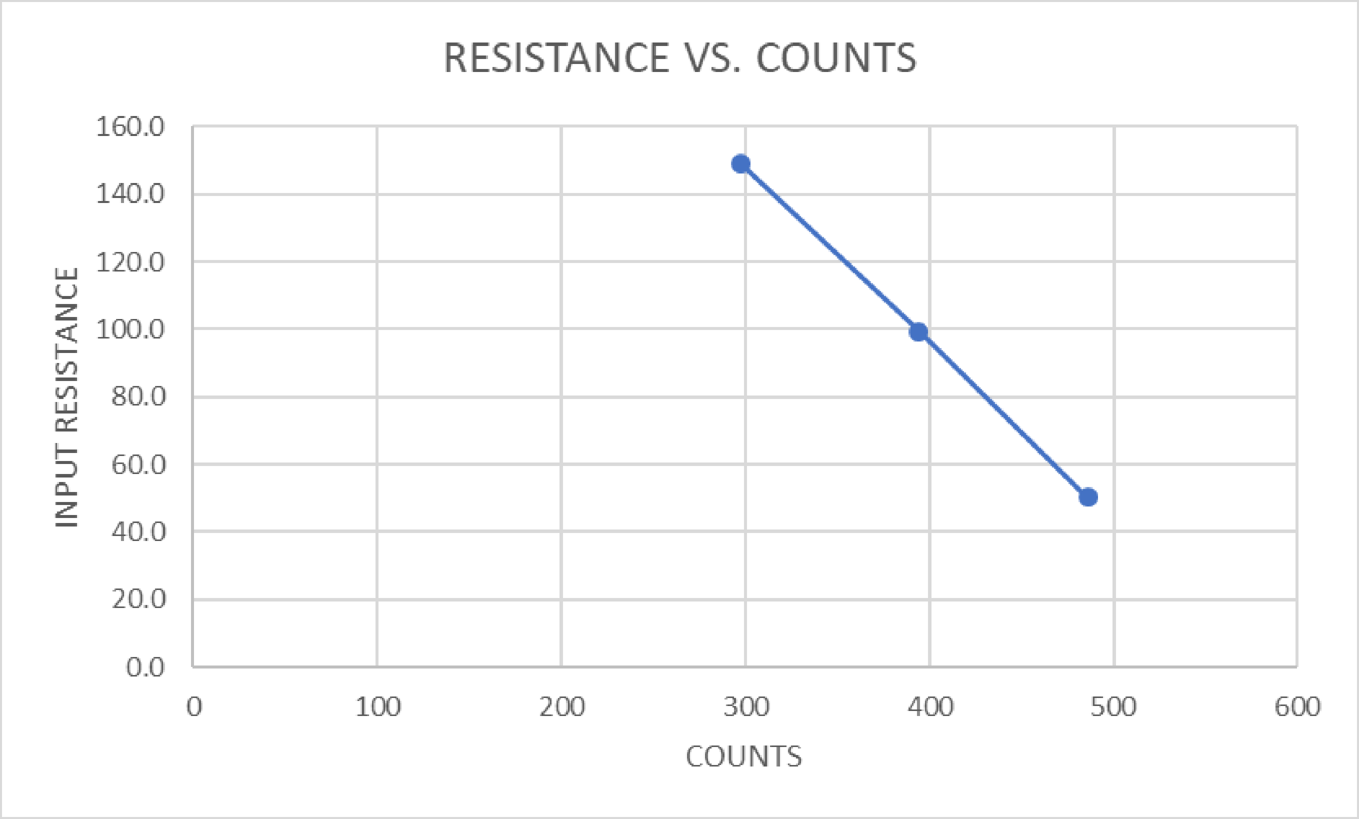



```
int volt_read = analogRead(VAPin);
float voltage = volt_read * SLOPE + Y_INT;
```

# Resistance Curve Fit

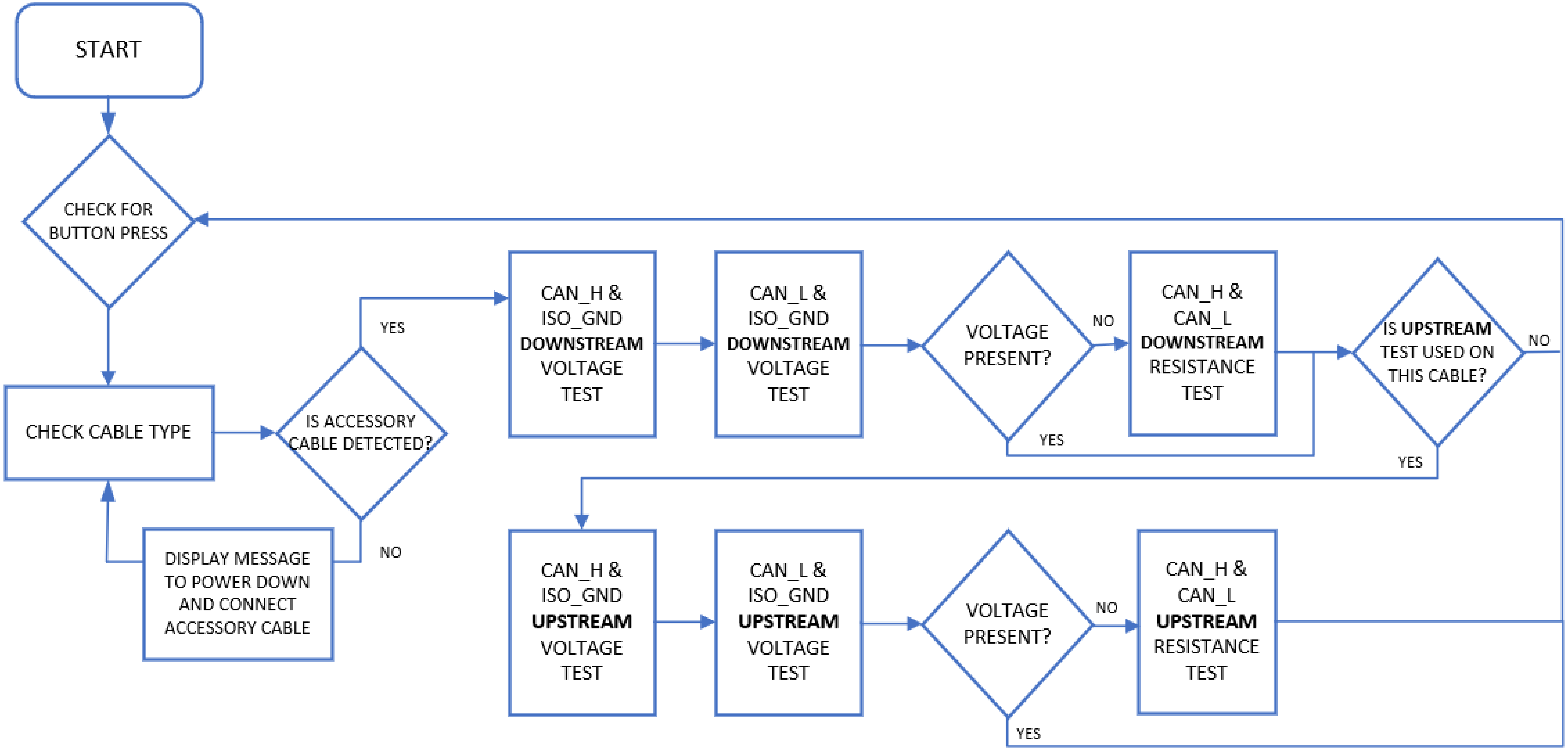
| INPUT RESISTANCE | COUNTS |
|---|---|
| 50.3 | 486 |
| 99.4 | 394 |
| 149.2 | 297 |

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.999937435 |
| R Square | 0.999874873 |
| Adjusted R Square | 0.999749746 |
| Standard Error | 0.782276645 |
| Observations | 3 |
| | |
| ANOVA | |
| | *df* |
| Regression | 1 |
| Residual | 1 |
| Total | 2 |
| | |
| | *Coefficients* |
| Intercept | 304.8986137 |
| X Variable 1 | -0.523191029 |




```
int counts = analogRead(ARPin);
float ohms = counts * SLOPE + Y_INT;
```

# Functional Flow Diagram - DEMO



# Resistance Test Setup

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| | | A | B | C | D | E | F | G | H | I | J | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | | CHAS_GND_UP |
| 2 | | | | | | | | | | | | ISO_GND_UP |
| 3 | | | | | | | | | | | | |
| 4 | BROWN | 1 | | | | | | | | | | CAN_H_UP |
| 5 | | | | | | | | | | | | |
| 6 | | | | | 50 Ω | | | SHORT | | 100 Ω | | |
| 7 | | | | | | | | | | | | |
| 8 | RED | 2 | | | | | | | | | | CAN_L_UP |
| 9 | | | | | | | | | | | | CHAS_GND_UP |
| 10 | | | | | | | | | | | | |
| 11 | ORANGE | 3 | | | | | | | | | | ISO_GND_UP |
| 12 | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | CAN_L_UP |
| 14 | | | | | | | | | | | | |
| 15 | PINK | 4 | | | | | | | | | | CHAS_GND_UP |
| 16 | | | | | | | | | | | | |
| 17 | | | | | | | | | | | | CHAS_GND_UP |
| 18 | | | | | | | | | | | | ISO_GND_UP |
| 19 | LT GREEN | 7 | | | | | | | | | | CAN_H_DN |
| 20 | | | | | | | | | | | | |
| 21 | | | 50 Ω | | | | | SHORT | | 100 Ω | | |
| 22 | | | | | | | | | | | | CAN_L_DN |
| 23 | BLUE | 8 | | | | | | | | | | CHAS_GND_UP |
| 24 | | | | | | | | | | | | |
| 25 | | | | | | | | | | | | |
| 26 | | | | | | | | | | | | ISO_GND_DN |
| 27 | LT BLUE | 9 | | | | | | | | | | |
| 28 | | | | | | | | | | | | |

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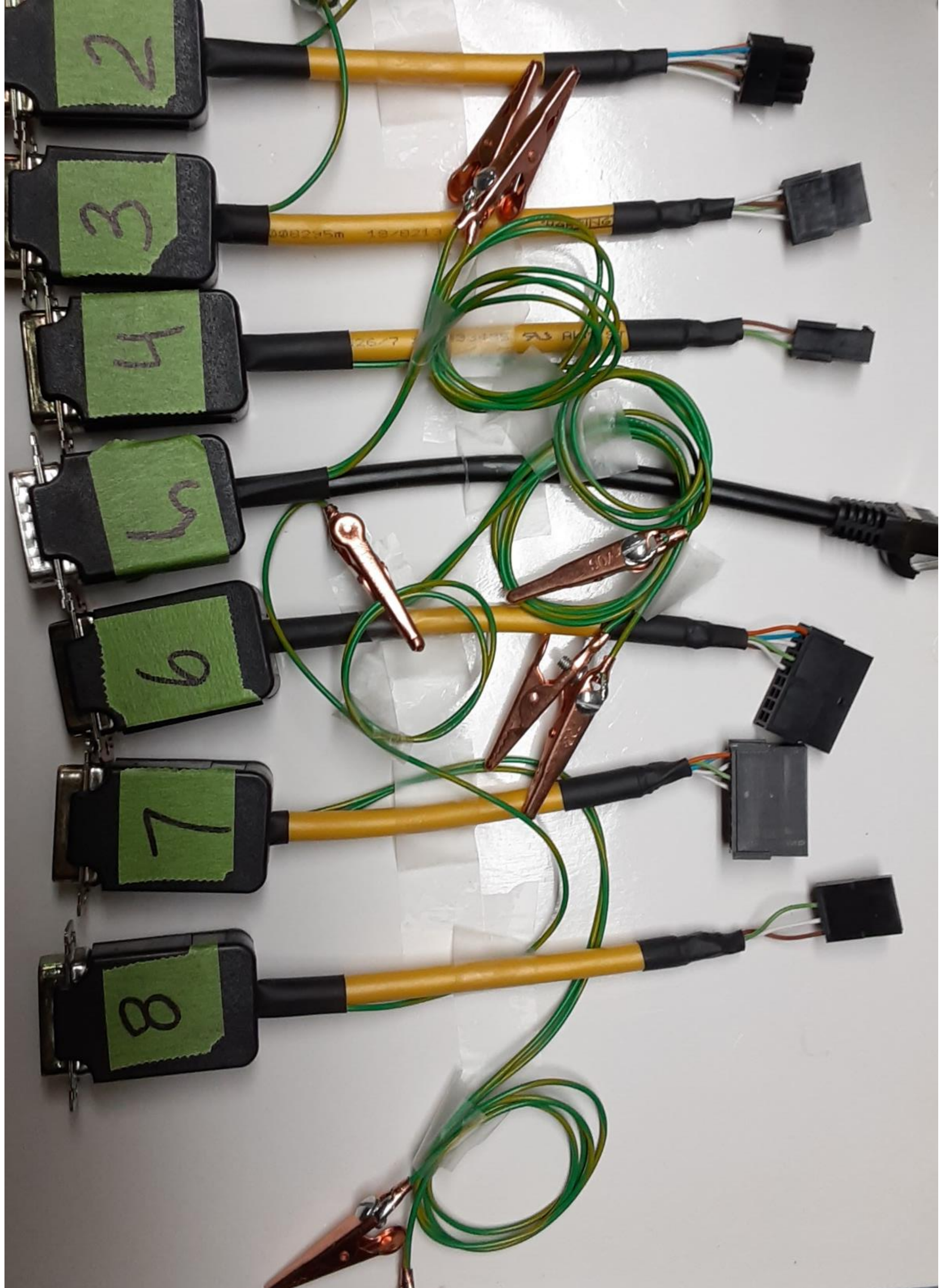
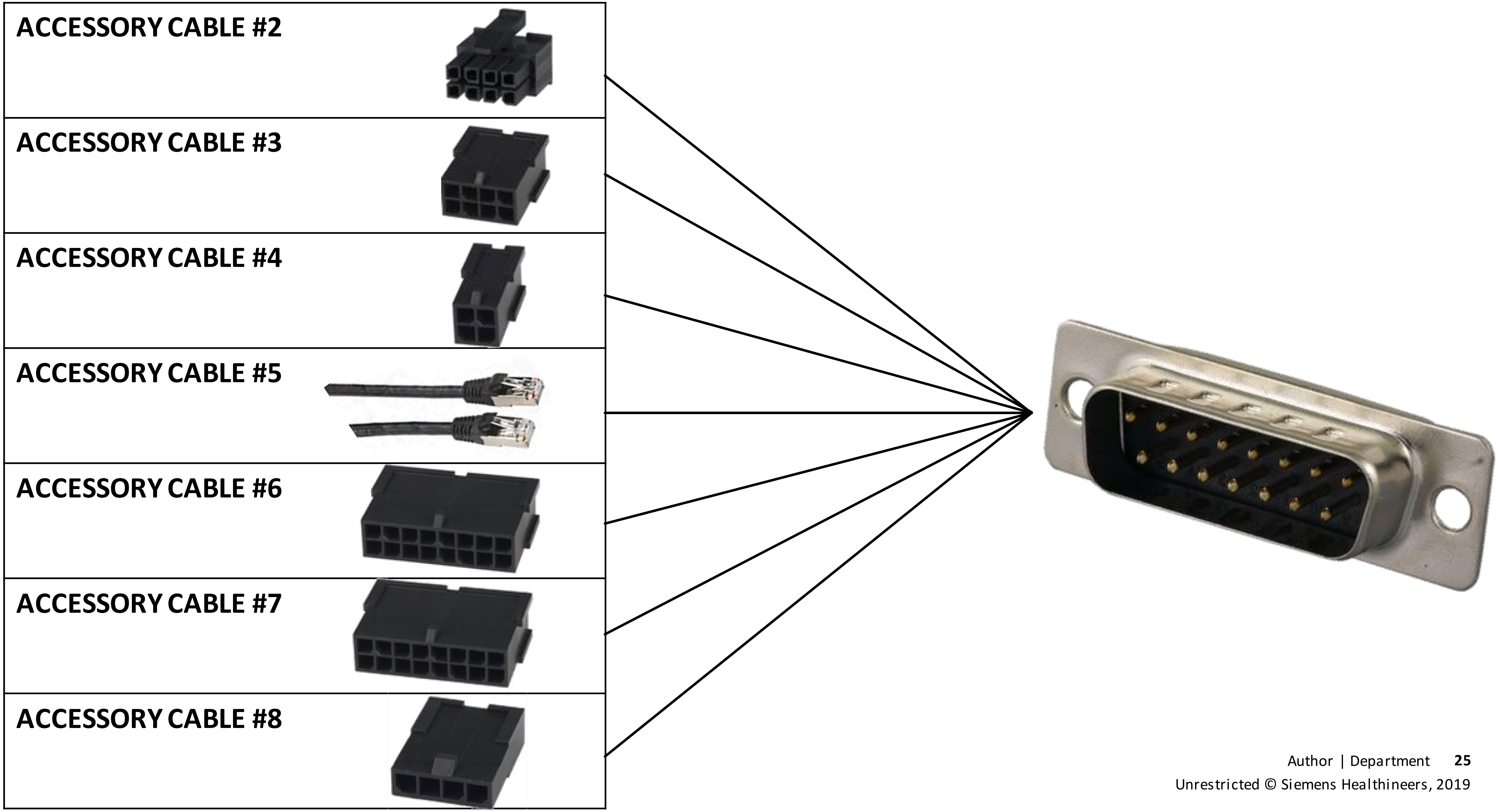
# 9. Tester Cables



# Accessory Cables



# CABLE #1 (111) – Common Cable

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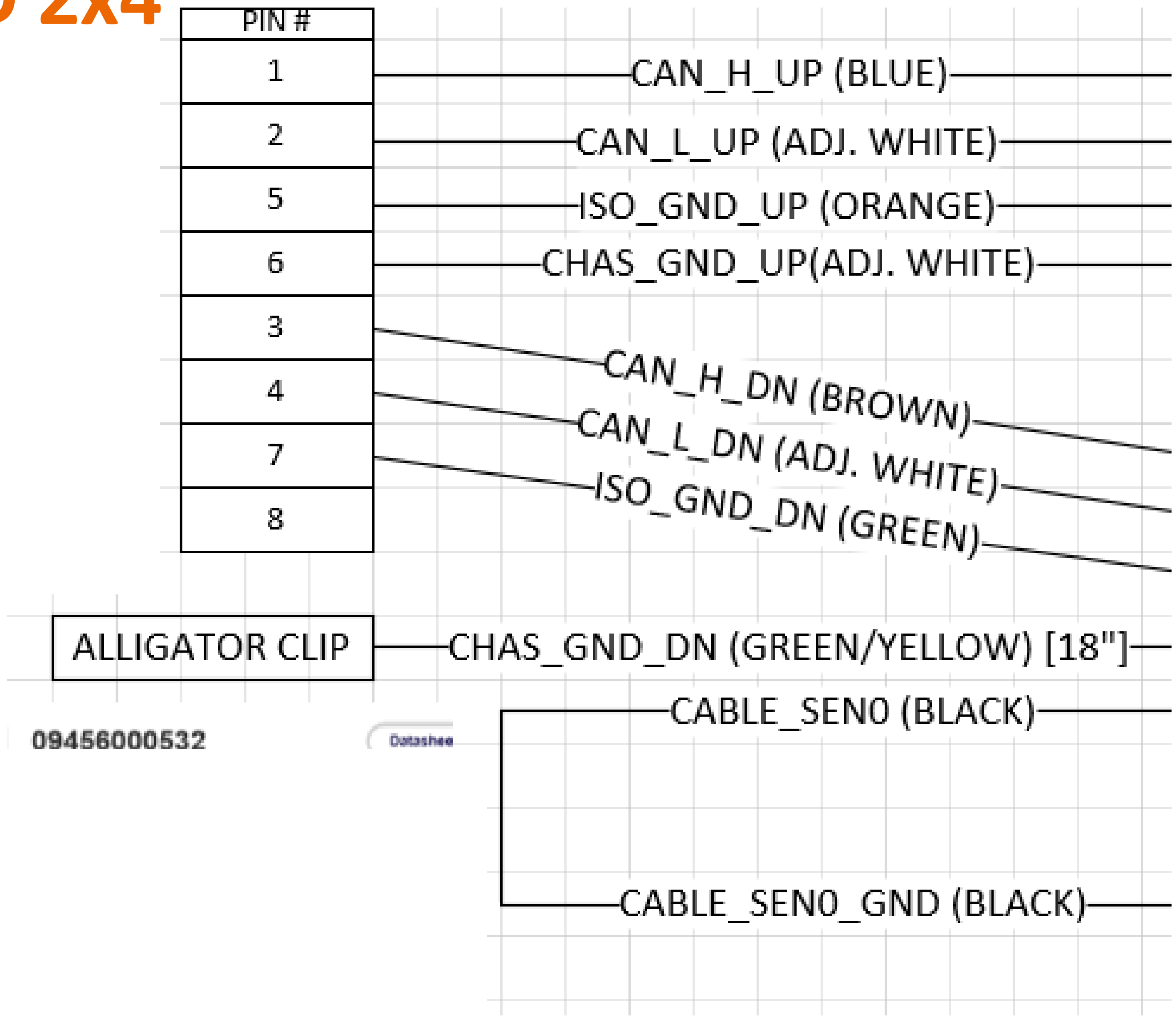
| PIN # | | PIN # |
|---|---|---|
| 1 | CAN_H_UP (WHITE W/TAN STRIPE) | 1 |
| 2 | CAN_L_UP (TAN W/WHITE STRIPE) | 2 |
| 3 | ISO_GND_UP (WHITE W/BROWN STRIPE) | 3 |
| 4 | CHAS_GND_UP(BROWN W/WHITE STRIPE) | 4 |
| 5 | CABLE_SEN2_GND (WHITE W/PINK STRIPE) | 5 |
| 6 | NC (PINK W/WHITE STRIPE) | 6 |
| 7 | CAN_H_DN (WHITE W/ORANGE STRIPE) | 7 |
| 8 | CAN_L_DN (ORANGE W/WHITE STRIPE) | 8 |
| 9 | ISO_GND_DN (WHITE W/YELLOW STRIPE) | 9 |
| 10 | CHAS_GND_DN (YELLOW W/WHITE STRIPE) | 10 |
| 11 | CABLE_SEN0 (WHITE W/GREEN STRIPE) | 11 |
| 12 | CABLE_SEN1 (GREEN W/WHITE STRIPE) | 12 |
| 13 | CABLE_SEN2 (WHITE W/BLUE STRIPE) | 13 |
| 14 | CABLE_SEN0_GND (BLUE W/WHITE STRIPE) | 14 |
| 15 | CABLE_SEN1_GND (WHITE W/VIOLET STRIP) | 15 |
| | EXTRA WIRE (VIOLET W/WHITE STRIPE) | |

# CABLE #2 (011) – INTO NETWORK uMATE-N-LOK FEM U/D 2x4



# CABLE #3 (101) – INTO DCM uMATE-N-LOK MALE D 2x4

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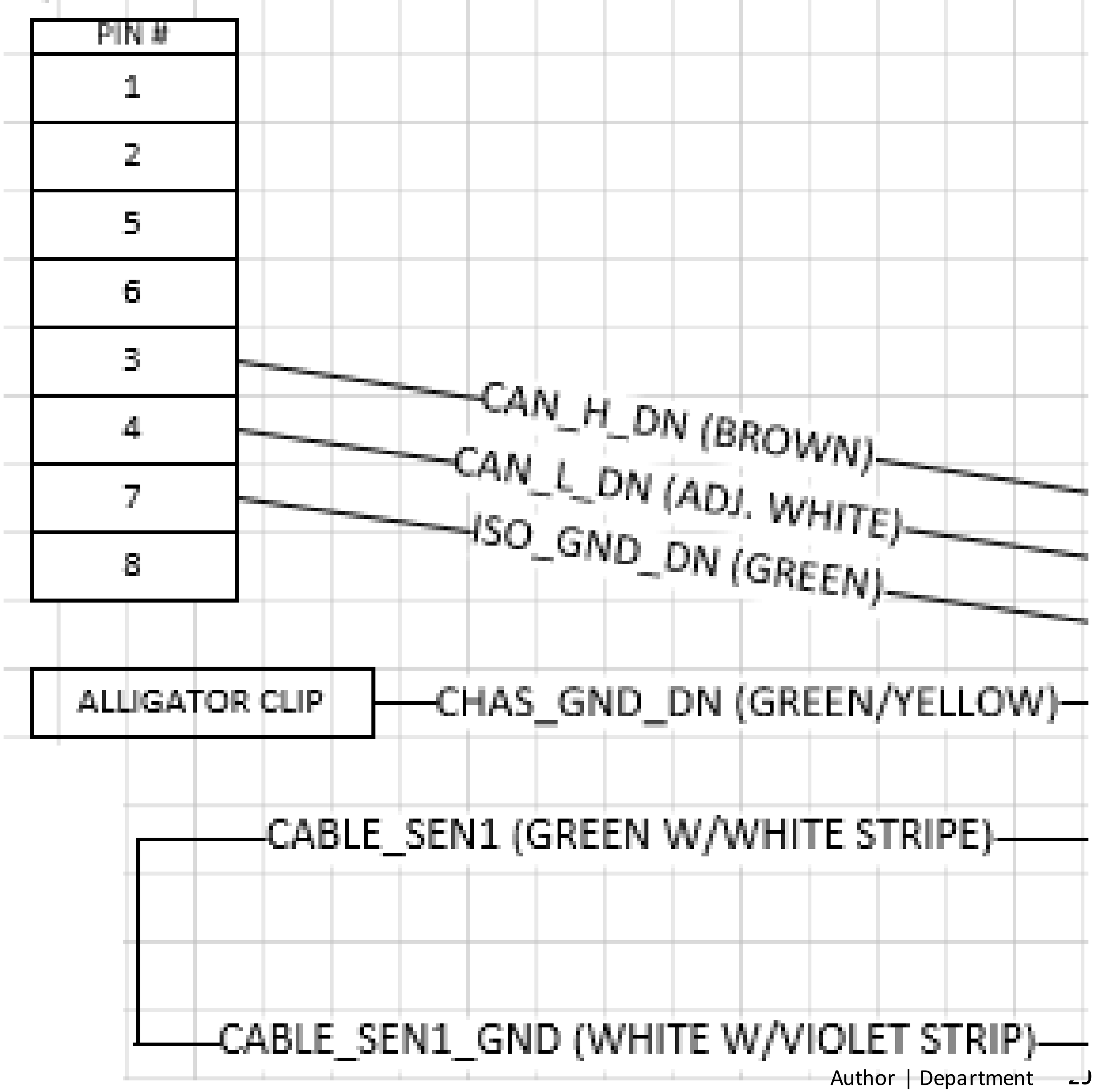
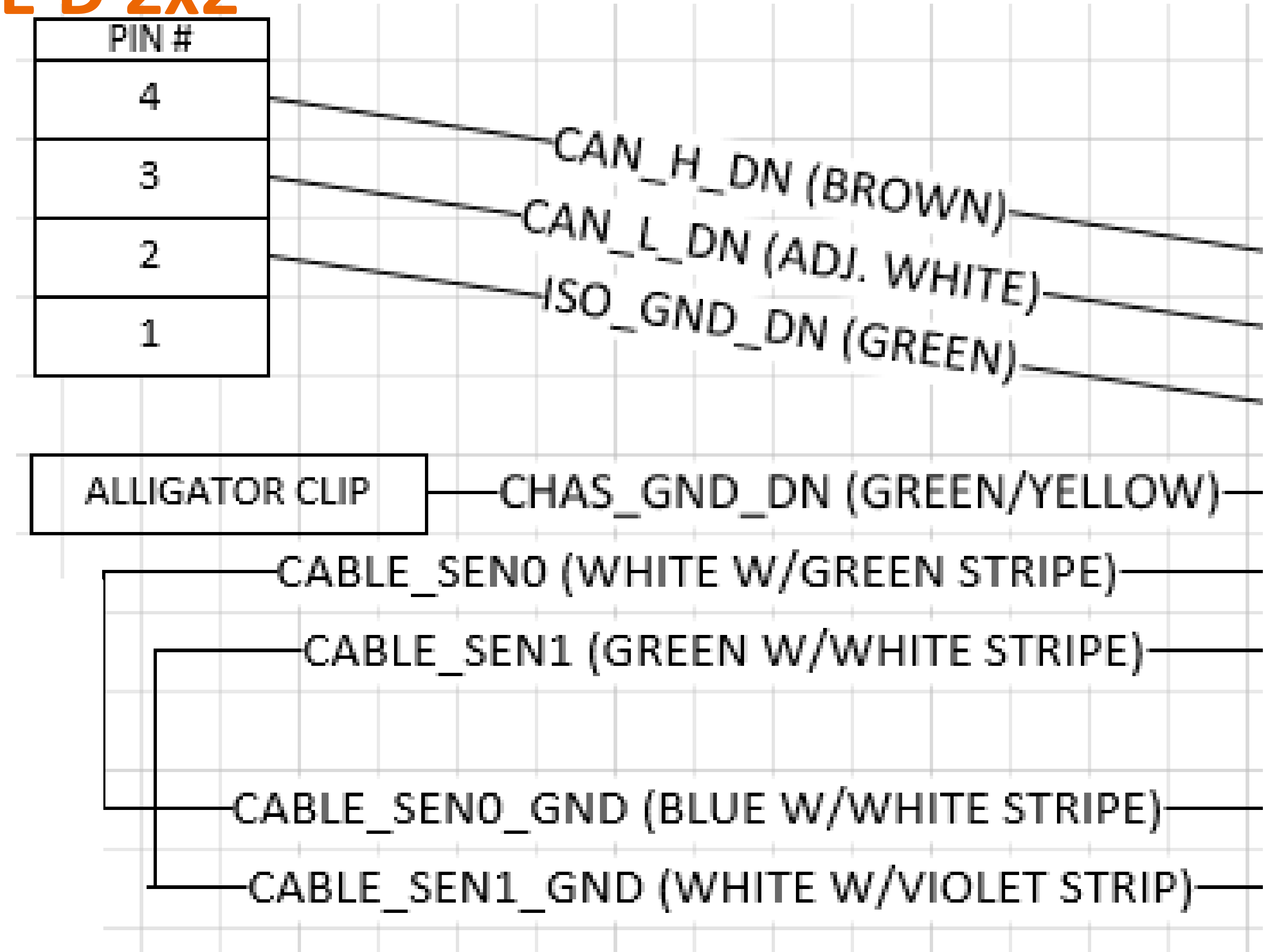
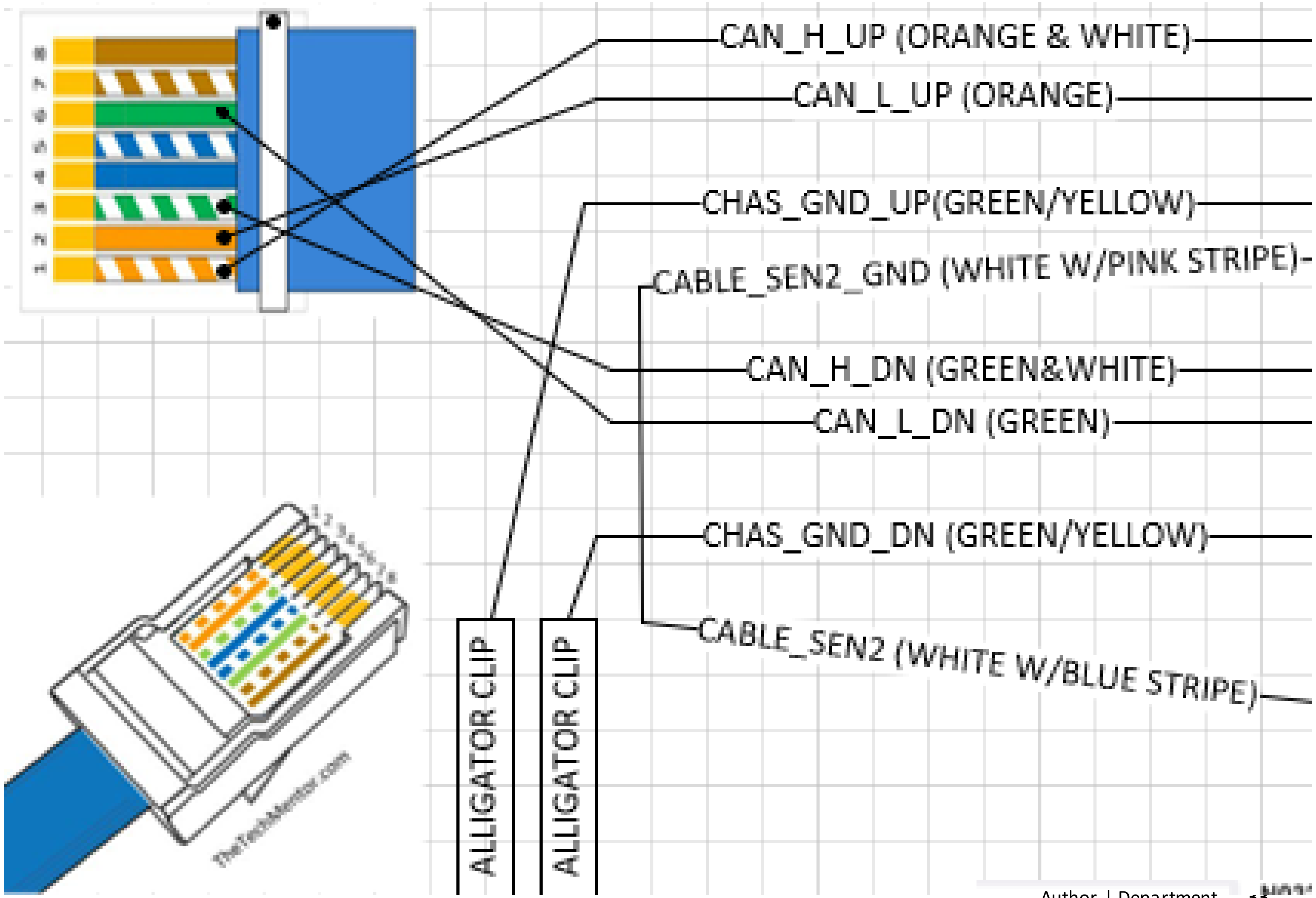


# CABLE #4 (001) – CAN FROM DC DIST uMATE-N-LOK MALE D 2x2

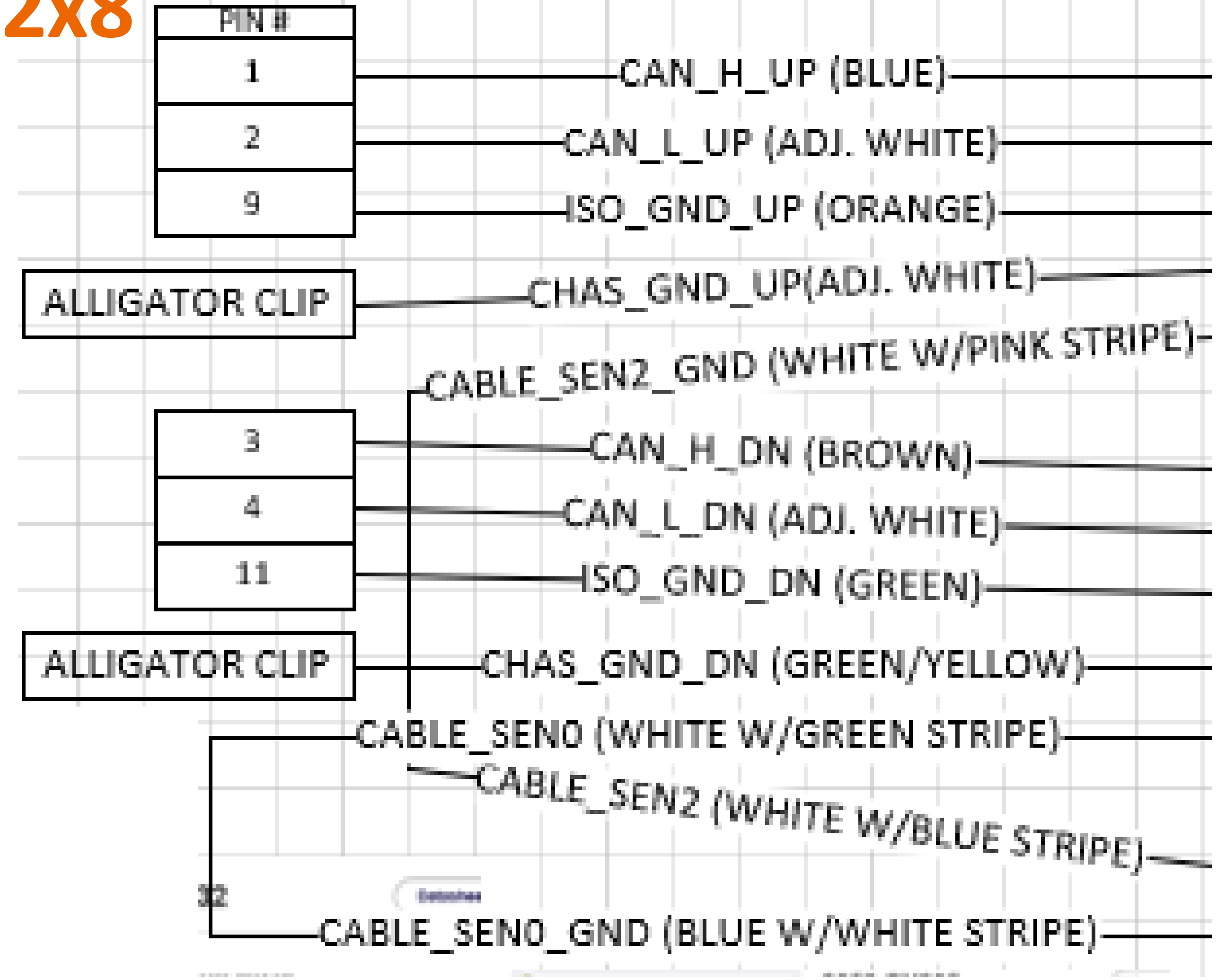


# CABLE #5 (110) – FROM LUMO D RJ45

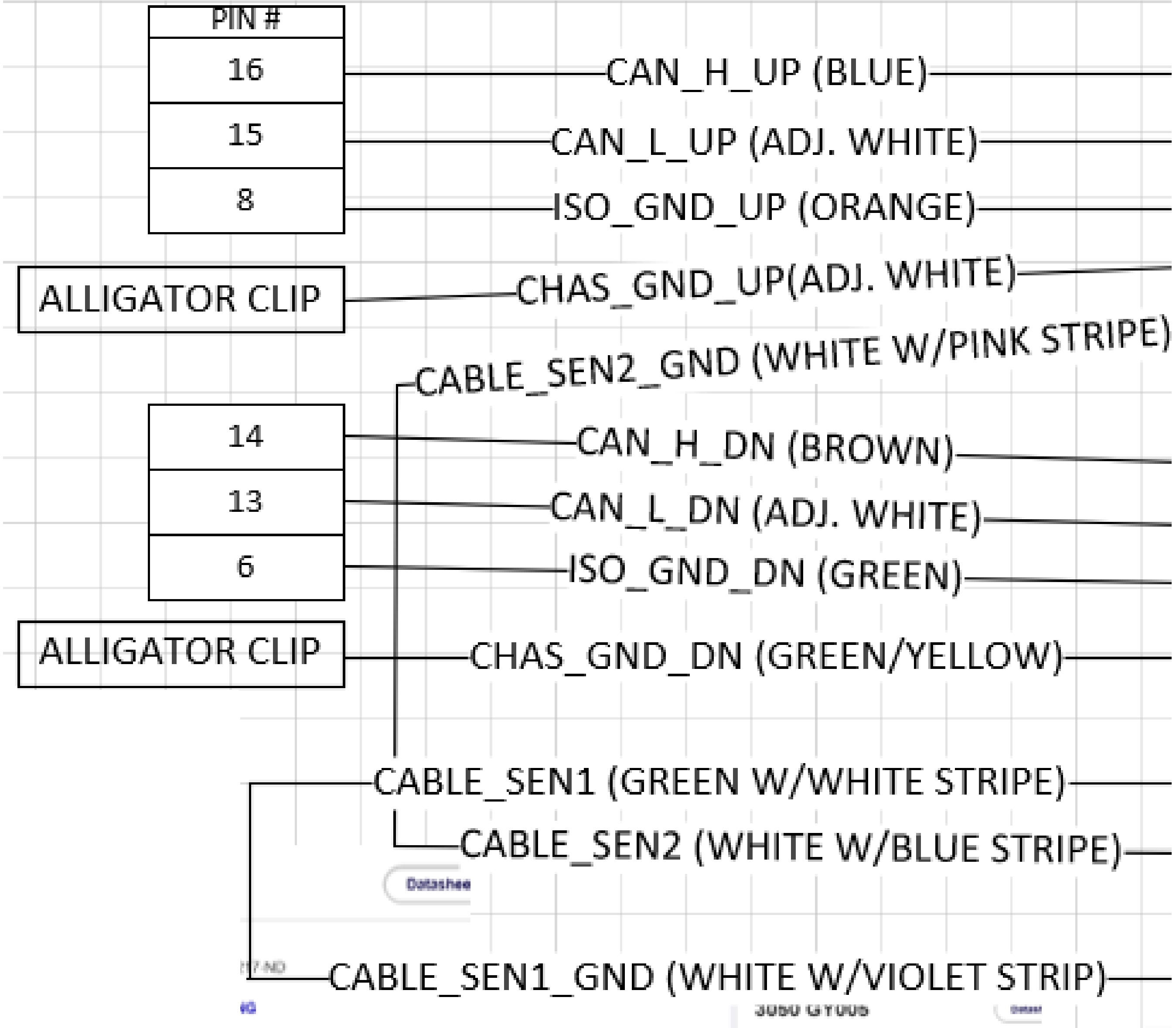




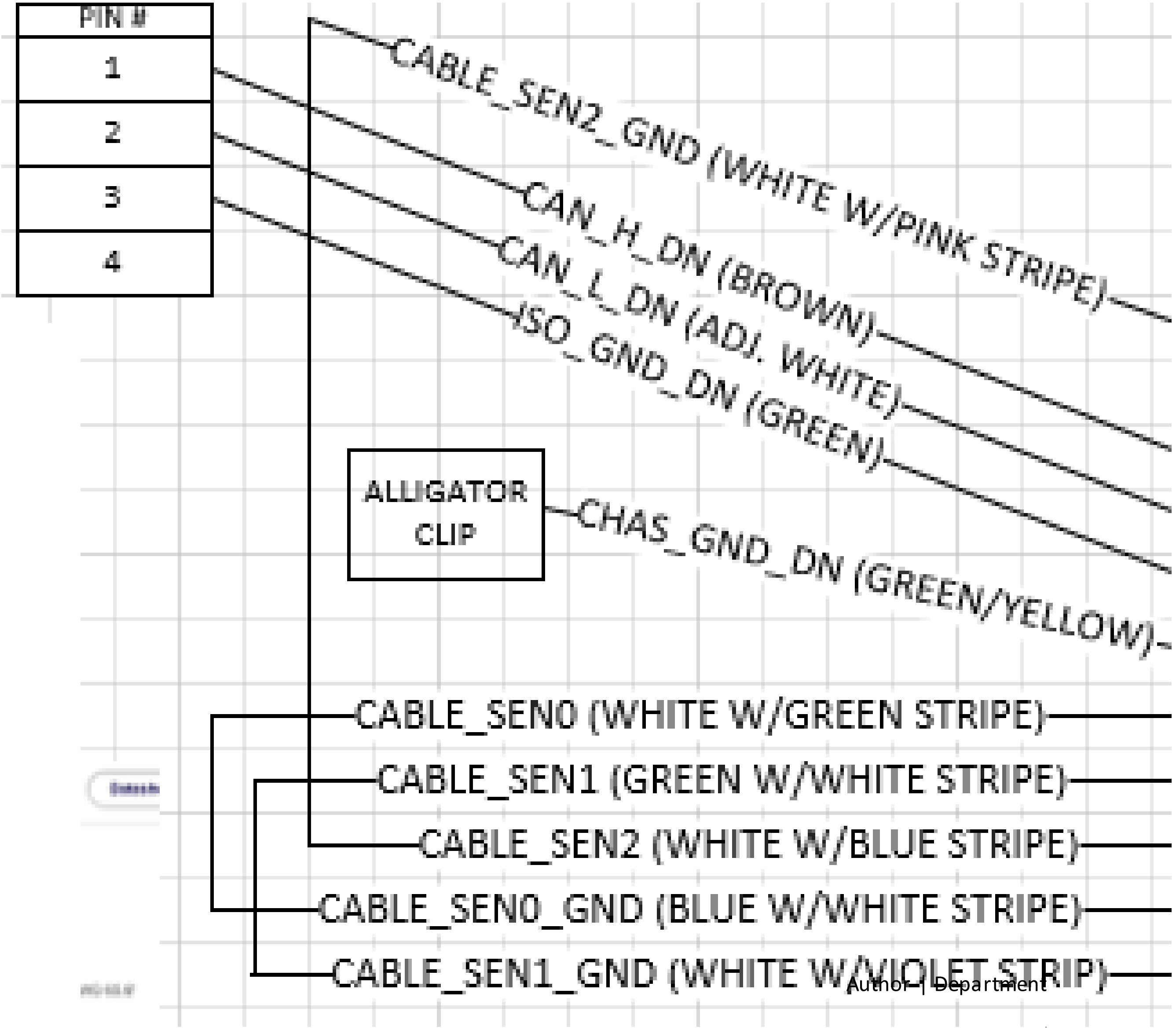
# CABLE #6 (010) – GANTRY IA CAN uMATE-N-LOK MALE U/D 2x8



# CABLE #7 (100) – GANTRY BULK CAN uMATE-N-LOK



# CABLE #8 (000) – KVASSER PROTO CABLE uMATE-N-LOK MALE D 1x4



# Cable Test Cases

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| CABLE 1 |
| --- |
| *COMMON CABLE* |
| 111 |
| CAN_H_UP |
| CAN_L_UP |
| ISO_GND_UP |
| CHAS_GND_UP |
| CAN_H_DN |
| CAN_L_DN |
| ISO_GND_DN |
| CHAS_GND_DN |

## 2 DIRECTION

| CABLE 2 | CABLE 5 | CABLE 6 | CABLE 7 |
| --- | --- | --- | --- |
| *uMATE-N-LOK FEM U/D* | *LUMO D RJ45* | *uMATE-N-LOK MALE 2x8* | *GANTRY BULK CAN uMATE-N-LOK MALE U/D 2x8* |
| 011 | 110 | 110 | 011 |
| CAN_H_UP | CAN_H_UP | CAN_H_UP | CAN_H_UP |
| CAN_L_UP | CAN_L_UP | CAN_L_UP | CAN_L_UP |
| ISO_GND_UP | CHAS_GND_UP | ISO_GND_UP | ISO_GND_UP |
| CHAS_GND_UP | CAN_H_DN | CHAS_GND_UP | CHAS_GND_UP |
| CAN_H_DN | CAN_L_DN | CAN_H_DN | CAN_H_DN |
| CAN_L_DN | CHAS_GND_DN | CAN_L_DN | CAN_L_DN |
| ISO_GND_DN | | ISO_GND_DN | ISO_GND_DN |
| CHAS_GND_DN | | CHAS_GND_DN | CHAS_GND_DN |

## 1 DIRECTION

| CABLE 3 | CABLE 4 | CABLE 8 |
| --- | --- | --- |
| *uMATE-N-LOK-MALE 4x4* | *u-MATE-N-LOK MALE 2x2* | *KVASSER* |
| 101 | 001 | 000 |
| CAN_H_DN | CAN_H_DN | CAN_H_DN |
| CAN_L_DN | CAN_L_DN | CAN_L_DN |
| ISO_GND_DN | ISO_GND_DN | ISO_GND_DN |
| CHAS_GND_DN | CHAS_GND_DN | CHAS_GND_DN |

# 10. Issues encountered

Board Issues:

- OP-AMP + and – terminals reversed in schematic and layout of shield PCB
- One digital input pin did not read properly so jumped wire to another available pin

Experimental Setup Issues:

- When grounding power supply to test circuit, regulation circuit brought CAN_H and CAN_L voltages close together when termination resistor was present. Workaround was to test voltages without resistors in place.
- When measuring resistance, power supply connections corrupted resistance values even with power supply being off. Workaround was to completely connect power supplies for resistance testing.

Firmware Issues:

- Although smaller voltage and resistance measurement applications work fine, there is an issue with reading correct voltages in fully integrated application

# 11. Conclusion and Next Steps

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Concept appears to be workable after initial testing on the bench. With only 50% memory flash usage, there is room for expanding or rewriting firmware routines.

Immediate Next Steps:

- Debug integrated application

Long-term Next Steps:

- Re-spin board to correct issues that required reworks
- Add battery check circuit
- Test unit when connected to active CAN network on bench as well as an instrument in active and passive states