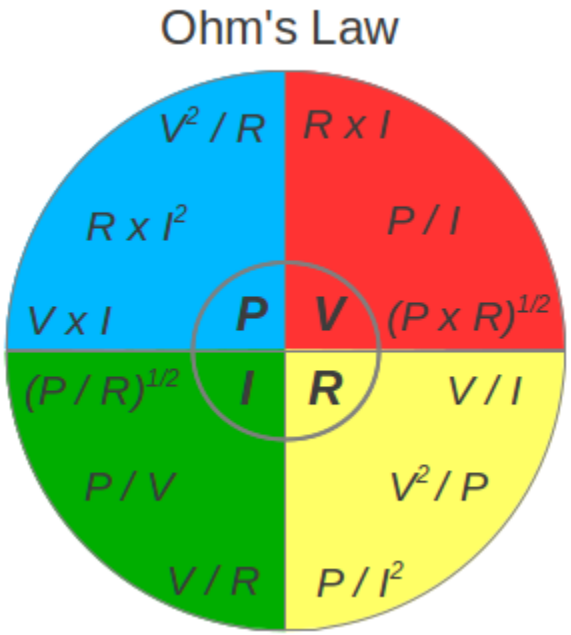
Electrical Basics



Electrical Potential - Ohm's Law

Ohm's law can be expressed as:

$V = R\,I$ (1a)

$V = P / I$ (1b)

$V = (P\,R)^{1/2}$ (1c)

Electric Current - Ohm's Law

$I = V / R$ (2a)

$I = P / V$ (2b)

$I = (P / R)^{1/2}$ (2c)

Electric Resistance - Ohm's Law

$R = V / I$ (3a)

$R = V^2 / P$ (3b)

$R = P / I^2$ (3c)

Example - Ohm's law

A *12 volt* battery supplies power to a resistance of *18 ohms*.

$I = (12\ V) / (18\ \Omega)$

$= 0.67\ (A)$

Common electrical units used in formulas and equations are:

- **Volt** - unit of electrical potential or motive force - potential is required to send one ampere of current through one ohm of resistance
- **Ohm** - unit of resistance - one ohm is the resistance offered to the passage of one ampere when impelled by one volt
- **Ampere** - units of current - one ampere is the current which one volt can send through a resistance of one ohm
- **Watt** - unit of electrical energy or power - one watt is the product of one ampere and one volt - one ampere of current flowing under the force of one volt gives one watt of energy

Electrical Basics

Resistance and Resistivity

Electrical resistance and resistivity

Electrical resistance of an electrical conductor depends on

- the length of the conductor
- the material of the conductor
- the temperature of the material
- the cross-sectional area of the conductor

and can be expressed as

$R = \rho l / A \qquad (1)$

where

R = resistance of the conductor (ohms, Ω)

ρ = resistivity of the conductor material (ohm meter, Ω m)

l = length of conductor (m)

A = cross-sectional area of conductor (m^2)

Resistivity of some Common Conductors

- Aluminum: *2.65 x 10^{-8} Ω m (0.0265 μΩ m)*
- Carbon: *10 x 10^{-8} Ω m (0.10 μΩ m)*
- Copper: *1.724 x 10^{-8} Ω m (0.0174 μΩ m)*

Example:
What is the resistance of 1m length of 16AWG copper wire?

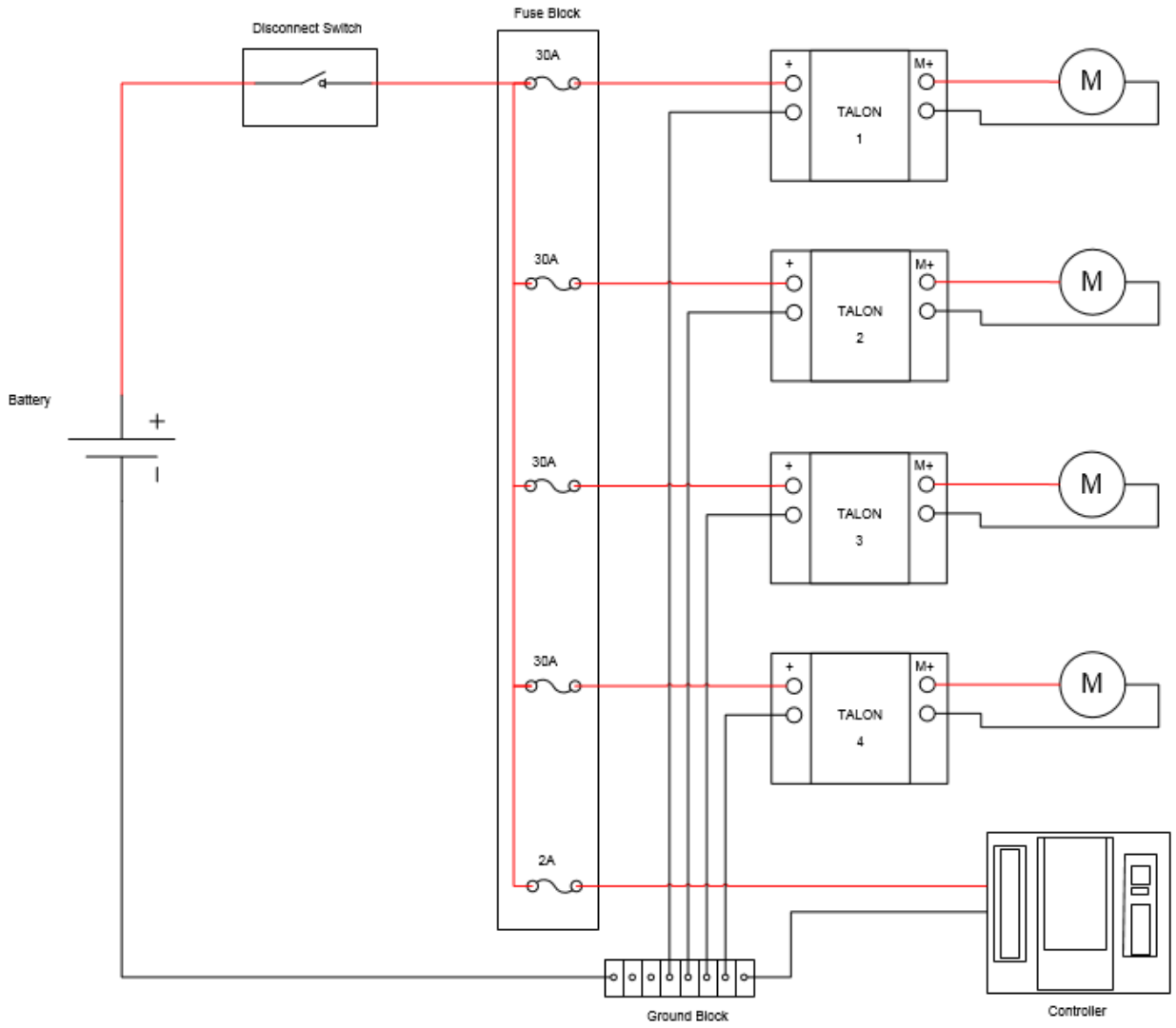
$\rho = 1.724 \times 10^{-8}\ \Omega\ m$
$L = 1\ m$
$A = 1.3087 \times 10^{-6}\ m^2$

$R = \rho L / A$
$R = 0.01724 * 1 / 1.3087$
$R = 0.013$ ohms

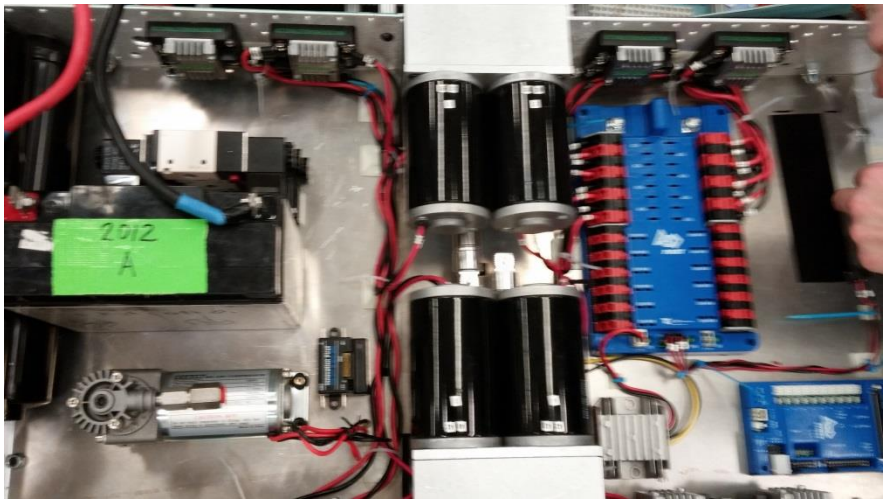
Electrical Wire Guage

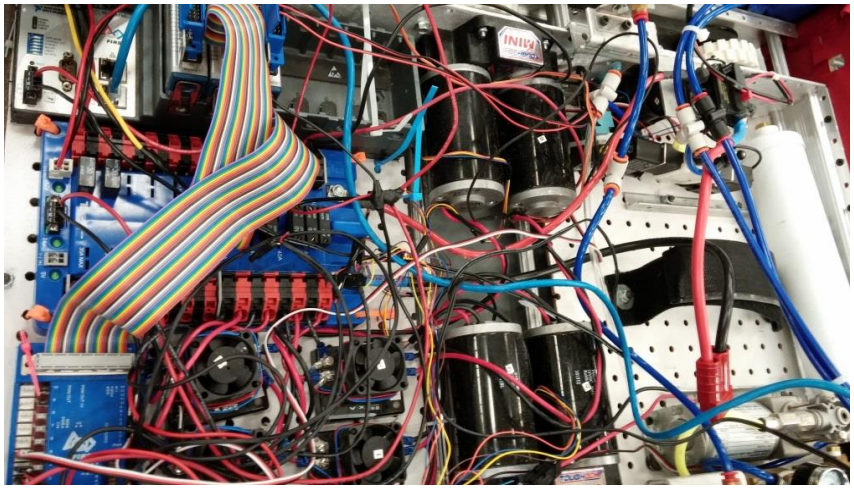
Wire Gage		Wire Diameter		Cross-Sectional Area			Operating	Fusing	1'C	20'C	60'C	100'C
AWG	Metric	Mils	mm	Cir.Mils	Sq.Mils	Sq.mm	Current[A]	Current[A]	Current[A]	Current[A]	Current[A]	Current[A]
6	-	162.0000	4.1148	26,244.0000	20,611.9894	13.2980	26.596	667.749	120.195	253.745	427.359	534.199
7	-	144.3000	3.6652	20,822.4900	16,353.9454	10.5509	21.102	561.358	101.044	213.316	359.269	449.087
8	-	128.5000	3.2639	16,512.2500	12,968.6908	8.3669	16.734	471.732	84.912	179.258	301.908	377.386
9	-	114.4000	2.9058	13,087.3600	10,278.7885	6.6315	13.263	396.259	71.327	150.579	253.606	317.008
10	-	101.9000	2.5883	10,383.6100	8,155.2682	5.2615	10.523	333.121	59.962	126.586	213.197	266.497
11	-	90.7400	2.3048	8,233.7476	6,466.7702	4.1721	8.344	279.923	50.386	106.371	179.151	223.938
12	-	80.8100	2.0526	6,530.2561	5,128.8511	3.3089	6.618	235.255	42.346	89.397	150.563	188.204
13	-	71.9600	1.8278	5,178.2416	4,066.9814	2.6239	5.248	197.687	35.584	75.121	126.519	158.149
14	-	64.0800	1.6276	4,106.2464	3,225.0384	2.0807	4.161	166.121	29.902	63.126	106.317	132.897
15	-	57.0700	1.4496	3,256.9849	2,558.0300	1.6503	3.301	139.622	25.132	53.056	89.358	111.697
16	-	50.8200	1.2908	2,582.6724	2,028.4262	1.3087	2.617	117.326	21.119	44.584	75.088	93.860
17	-	45.2600	1.1496	2,048.4676	1,608.8627	1.0380	2.076	98.608	17.749	37.471	63.109	78.886
18	-	40.3000	1.0236	1,624.0900	1,275.5573	0.8229	1.646	82.851	14.913	31.483	53.025	66.281
19	-	35.8900	0.9116	1,288.0921	1,011.6652	0.6527	1.305	69.631	12.534	26.460	44.564	55.705
20	-	31.9600	0.8118	1,021.4416	802.2384	0.5176	1.035	58.513	10.532	22.235	37.448	46.810
21	-	28.4600	0.7229	809.9716	636.1502	0.4104	0.821	49.169	8.850	18.684	31.468	39.335
22	-	25.3500	0.6439	642.6225	504.7145	0.3256	0.651	41.334	7.440	15.707	26.454	33.067
23	-	22.5700	0.5733	509.4049	400.0857	0.2581	0.516	34.725	6.250	13.195	22.224	27.780
24	-	20.1000	0.5105	404.0100	317.3087	0.2047	0.409	29.183	5.253	11.090	18.677	23.347
25	-	17.9000	0.4547	320.4100	251.6494	0.1624	0.325	24.526	4.415	9.320	15.696	19.621
26	-	15.9400	0.4049	254.0836	199.5568	0.1287	0.257	20.610	3.710	7.832	13.190	16.488
27	-	14.2000	0.3607	201.6400	158.3677	0.1022	0.204	17.329	3.119	6.585	11.091	13.863
28	-	12.6400	0.3211	159.7696	125.4828	0.0810	0.162	14.553	2.620	5.530	9.314	11.643
29	-	11.2600	0.2860	126.7876	99.5787	0.0642	0.128	12.236	2.203	4.650	7.831	9.789
30	-	10.0200	0.2545	100.4004	78.8543	0.0509	0.102	10.272	1.849	3.903	6.574	8.217
31	-	8.9280	0.2268	79.7092	62.6034	0.0404	0.081	8.639	1.555	3.283	5.529	6.911
32	-	7.9500	0.2019	63.2025	49.6391	0.0320	0.064	7.259	1.307	2.759	4.646	5.807

Electrical Schematic



Electrical Wiring
Good & Bad Examples





Which robot is more likely to fail?
Which robot is easier to troubleshoot?

12V Battery

FRC
FIRST® Robotics Competition

3024
POWERED BY DRAGON FIRE

MK POWERED

ES17-12

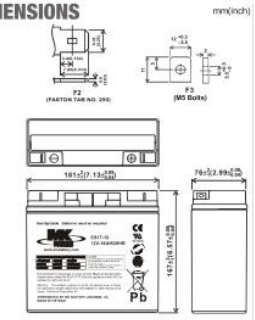
Maintenance-Free Rechargeable Sealed Lead-Acid Battery

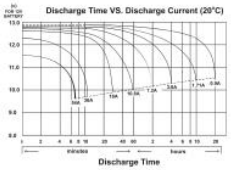
SPECIFICATIONS

Nominal Voltage (V)	12V
Nominal Capacity	
20 hour rate (0.9A to 10.50V)	18Ah
10 hour rate (1.8A to 10.50V)	17.1Ah
5 hour rate (3.06A to 10.20V)	15.3Ah
1C (18A to 9.60V)	8.1Ah
3C (54A to 9.60V)	6.3Ah
Weight	Approx. 13.82Lbs. (6.28kg)
Internal Resistance (at 1KHz)	10 mΩ
Maximum Discharge Current for 30 seconds :	360A
Maximum Discharge Current for 5 seconds :	720A
Operating Temperature Range	
Charge	0°C (32°F) to 40°C (104°F)
Discharge	-15°C (5°F) to 50°C (122°F)
Storage	-15°C (5°F) to 40°C (104°F)
Charge Retention (shelf life) at 20°C (68°F)	
1 month	92%
3 months	90%
6 months	80%
Charging Methods at 20°C (68°F)	
Cycle Use :	Charging Voltage 14.4 to 15.0V Maximum Charging Current : 5.4A
Standby Use :	Float Charging Voltage 13.50 to 13.80V
Life expectancy :	
Cycle Use :	100% depth of discharge 200 cycles 80% depth of discharge 225 cycles 50% depth of discharge 500 cycles
Standby Use :	3-5 years
Case Material :	ABS (Option : 94-HB & 94V-0 Flame Retardant Case Material)
Terminal :	F2 or F3

DIMENSIONS

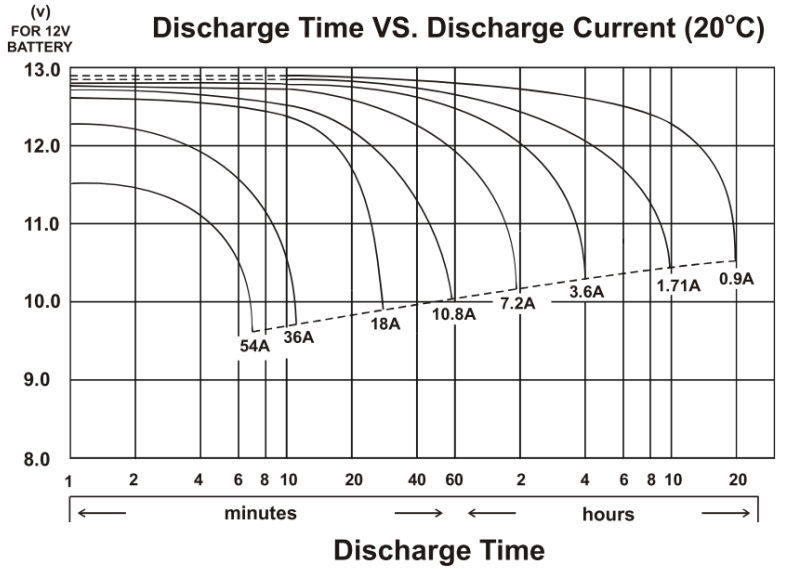
mm(inch)





MK Battery
1631 South Sinclair Street • Anaheim, California 92806
Toll Free: 800-372-9253 • Fax: 714-937-0818 • E-mail: sales@mkbattery.com

MK POWERED



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Maximum Discharge Current for 30 seconds :	360A
Maximum Discharge Current for 5 seconds :	720A

Motor Wiring

FRC
FIRST® Robotics Competition

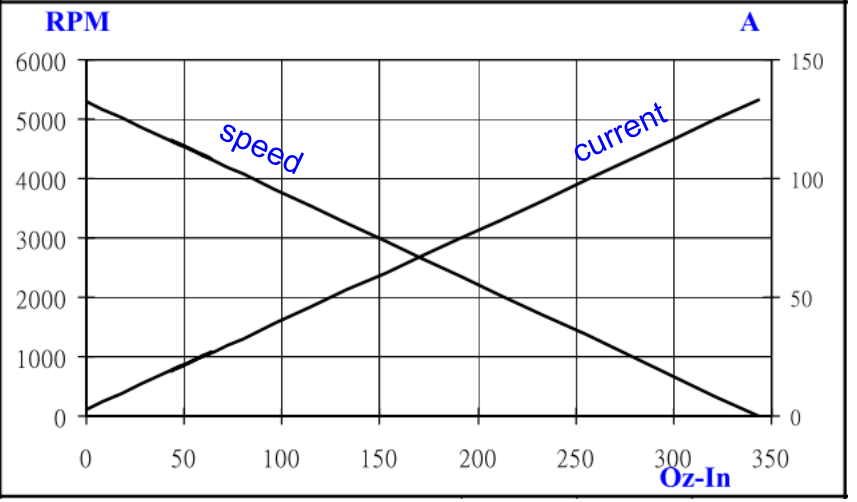
3024
POWERED BY DRAGON FIRE

TYPICAL PERFORMANCE @ 12 Vdc

	TORQUE	SPEED	CURRENT	POWER	EFF'CY
	Oz-In	RPM (±10%)	A MAX	Wo	%
FREE LOAD	0	5310	2.7	0	0%
NORMAL LOAD	64.0	4320	27	205	63%
@MAX EFFICIENCY	45.0	4614	19.8	154	65%
@MAX POWER	171.7	2655	67.9	337	41%
@STALL	343.4	0	133.0	0	0%

HIPOT: 600 Vac/0.5 mA/1 sec
INSULATION RESISTANCE: > 10.0 M Ohm MIN
INSULATION CLASS: B

PERFORMANCE CURVE



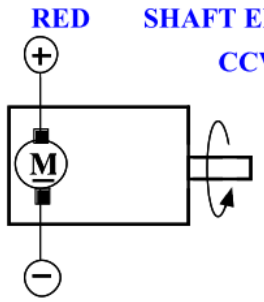
GENERAL FEATURES

(1) LEAD WIRE: AWG#14 UL#1015,105°

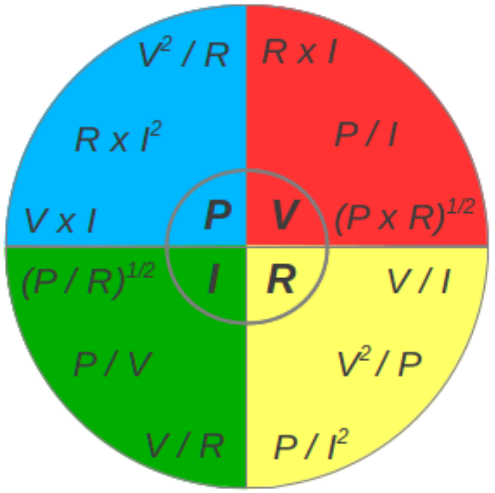
	LENGTH	STRIP LENGT	COLOR
W1	18.0 ± 0.5	0.5 ± 0.04	RED
W2	18.0 ± 0.5	0.5 ± 0.04	BLACK

(2) FINISHING:HOUSING POWDER GLOSS BLACK C(
(3) END-PLAY 0.005 ~ 0.02
(4) CONSTRUCTION: TENV.

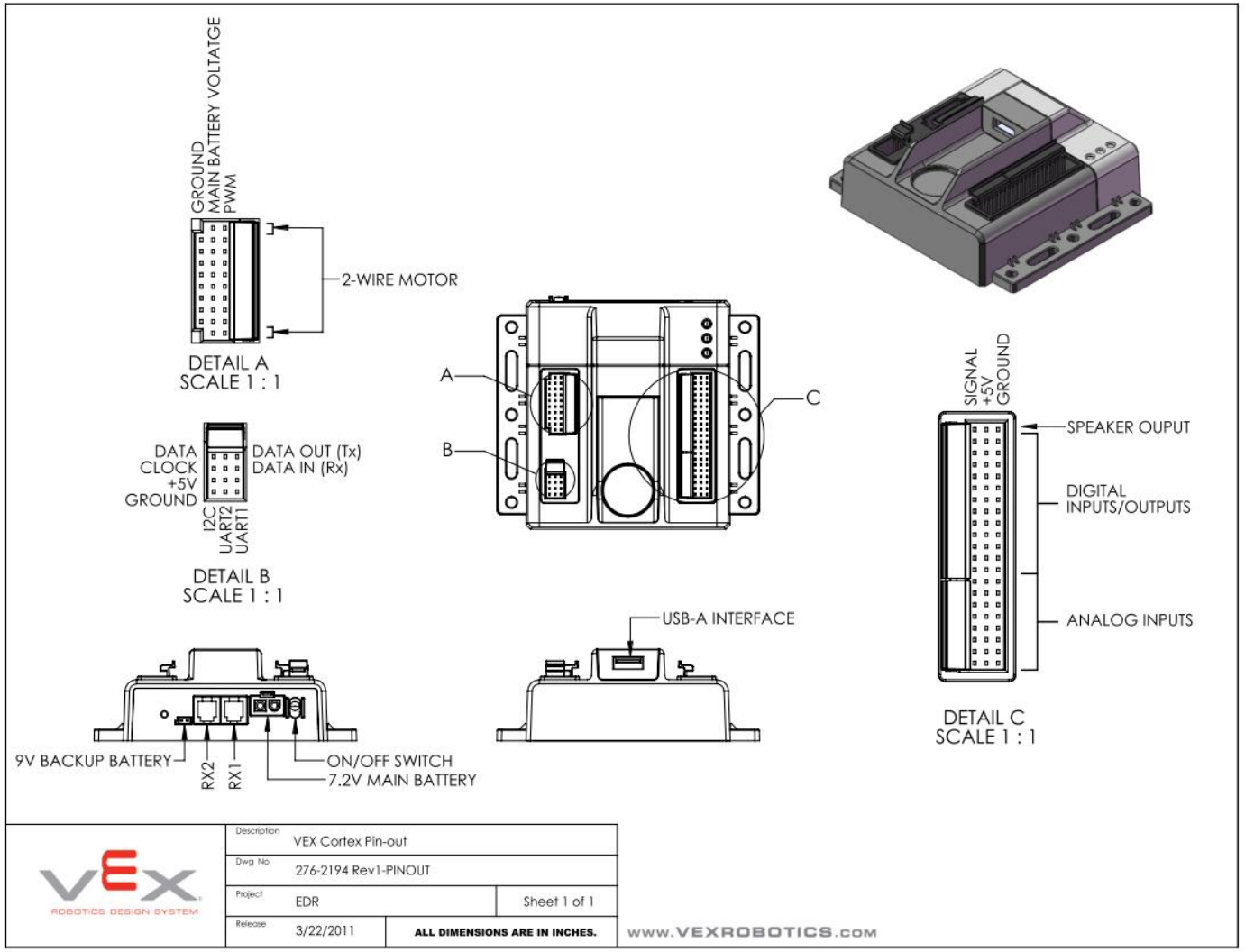
WIRING & ROTATION



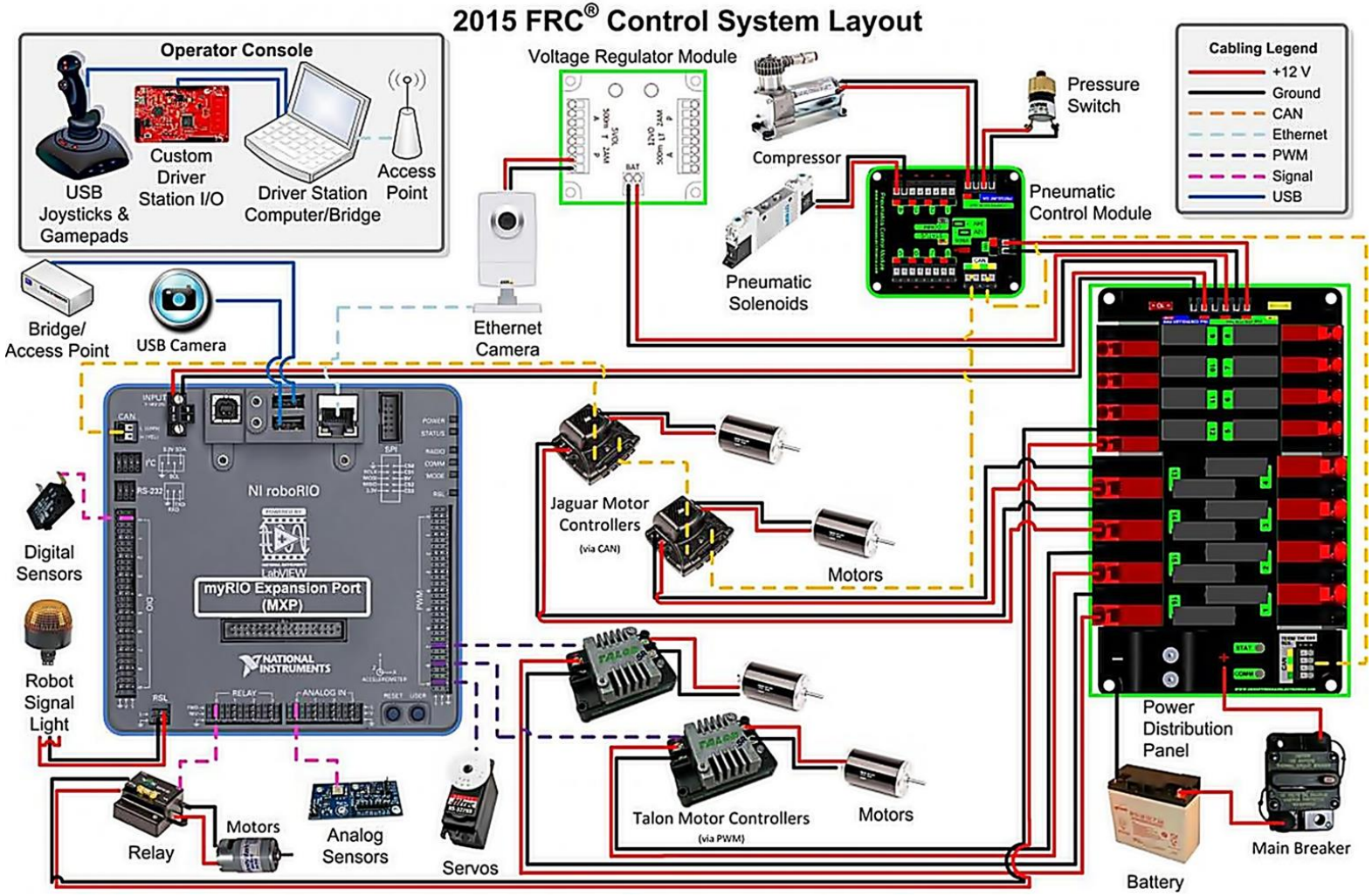
ROTATION: REVERSIBLE



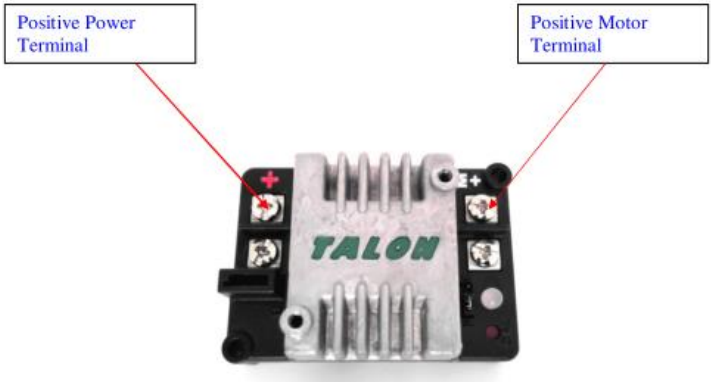
Vex Controller

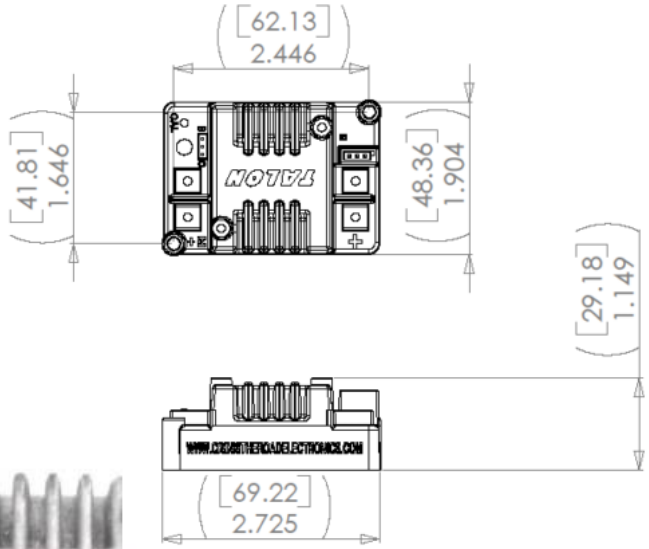


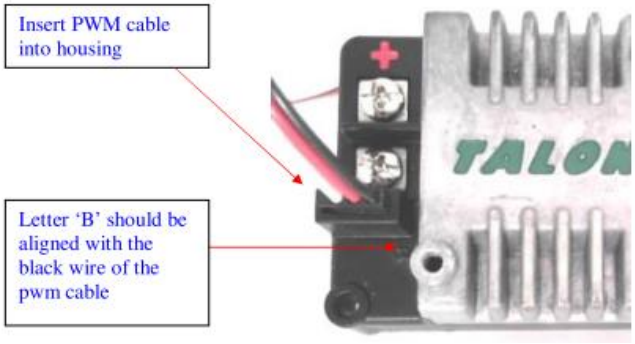
New FRC Control System



Week 3
Motor Drivers







Input voltage	6-28 VDC
Continuous current	60 A
Peak current	100 A
Input PWM signal	1-2 ms @ 333 Hz
Input resolution	10-bit (1024 steps)
Output resolution	10-bit (1024 steps)
Output switching frequency	15 kHz

Week 3
Motor Drivers

- The LED is used to indicate the direction and percentage of throttle and state of calibration.
- The LED may be one of three colors; **RED**, **ORANGE** or **GREEN**.
- A solid **GREEN** LED indicates positive output voltage equal to the input voltage of the Talon.
- A solid **RED** LED indicates an output voltage that is equal to the input voltage multiplied by -1. (input voltage = 12 volts, output equals -12 voltage).

- The LED will blink its corresponding color for any throttle less than 100% (**RED** indicates negative polarity, **GREEN** indicates positive).
- The rate at which the LED blinks is proportional to the percent throttle.
- The faster the LED blinks, the closer the output is to 100% in either polarity.
- The Talon SR has a more defined blink when transitioning between 100% throttle and 99%.

- The LED will blink **ORANGE** any time the Talon is in the disabled state.
- This will happen if the PWM input signal is lost, or in FRC, when the robot is disabled.
- If the Talon is in the enabled state and the throttle is within the 4% dead band, the LED will remain solid **ORANGE**.

- The Talon SR has an additional LED state that blinks **RED**/**ORANGE** when a fault state is detected.
- A fault can be caused by one of three things; under voltage (<3.3VDC), over temperature (>170^{o}C) or a shorted output transistor.
- During a fault, the output of the Talon is disabled until the fault condition is no longer present.