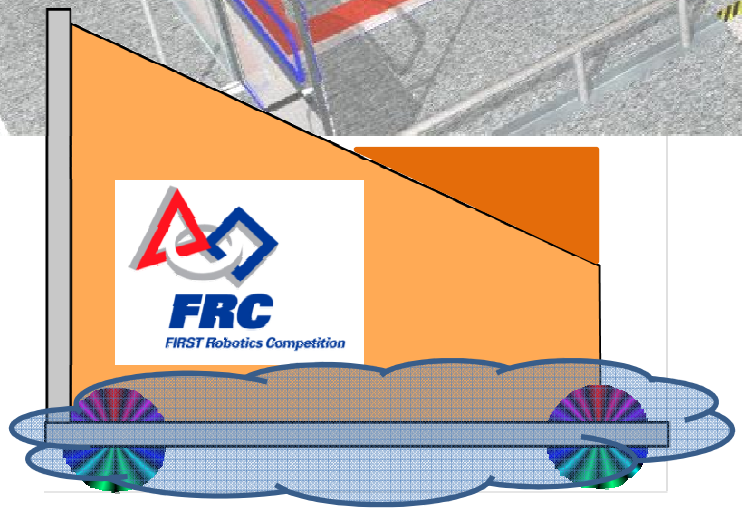
FRC ???

Motor/Gearbo[illegible]

- Making [illegible]s of your k[illegible]t of p[illegible]rts -

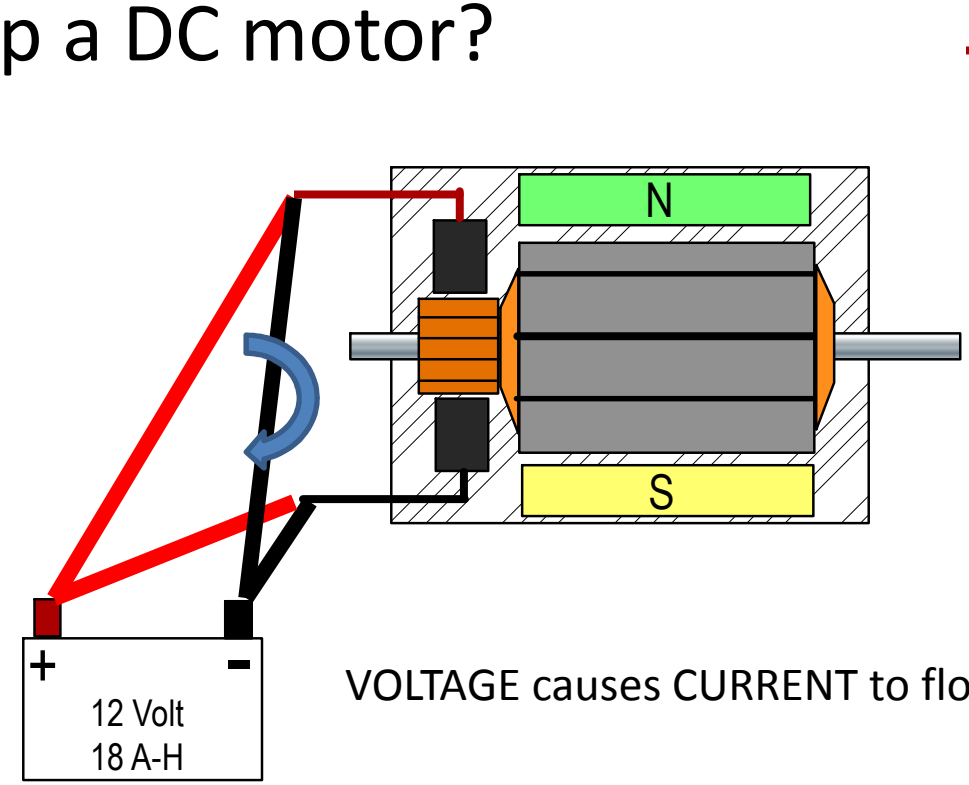


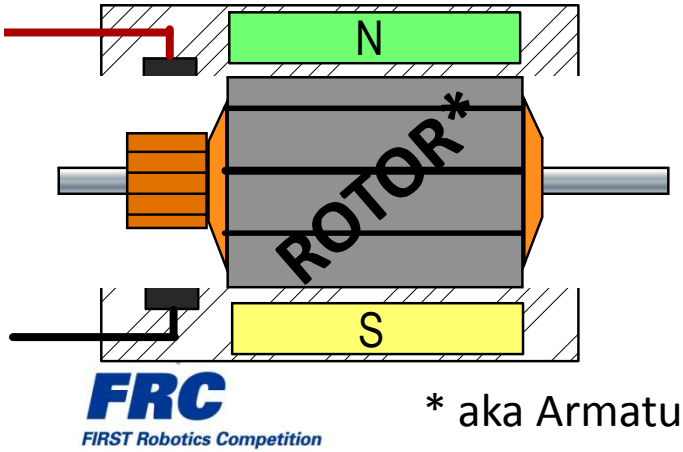
General Rule #1: The larger the motor the more work it can do

Mike Duello – Mentor, Team 1985 mdduello@sbcglobal.net

FRC Motors

- FIRST specifies that only specific brushed DC motors can be used on the robot. What makes up a DC motor?





* aka Armature

VOLTAGE causes CURRENT to flow in motor

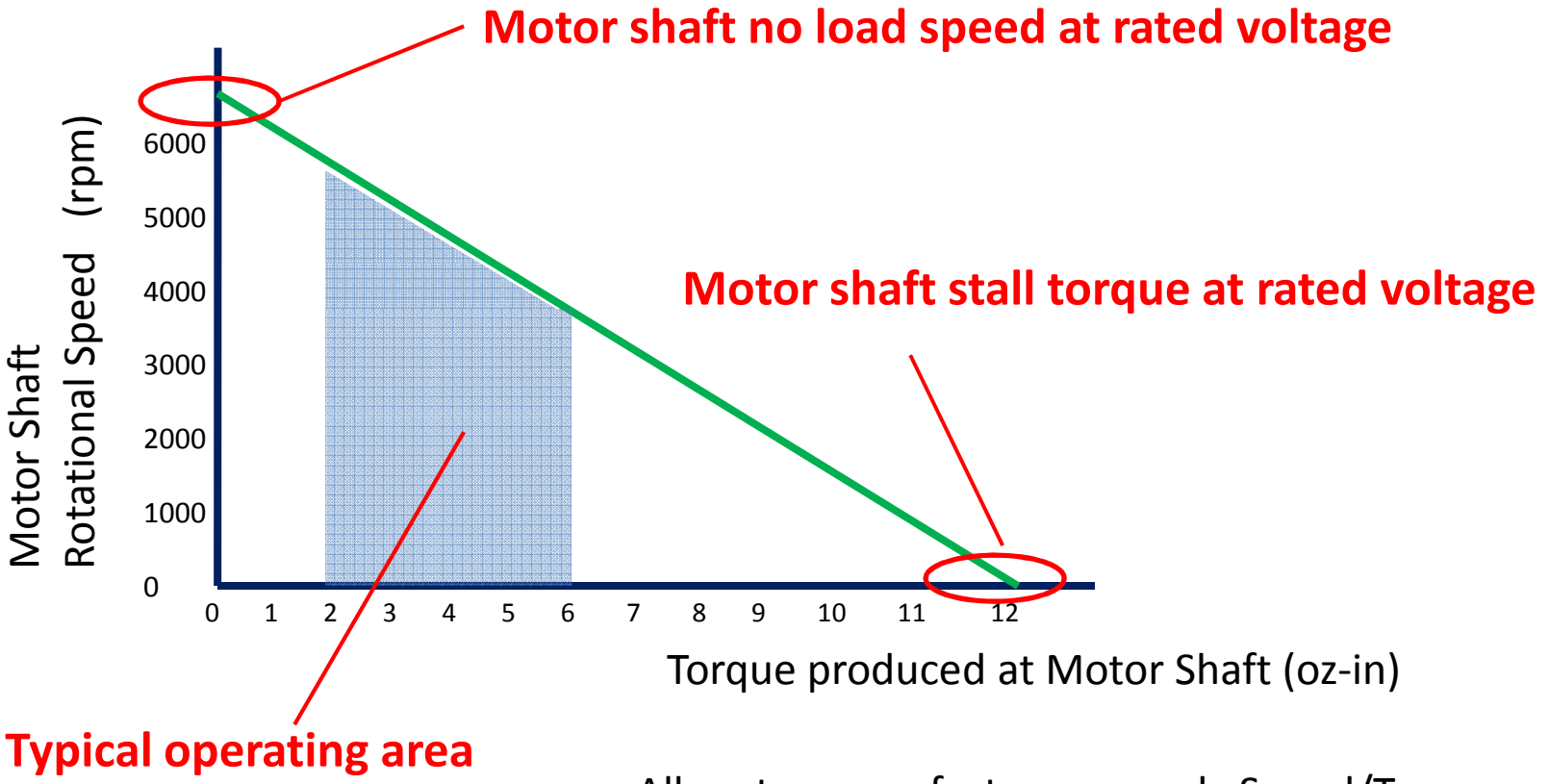
Battery = VOLTAGE Source

Motors are specified by

- Torque constant (K_t) oz-in/amp
- Speed constant (K_v) Krpm/volt

among other parameters

Motor Speed-Torque curve basics

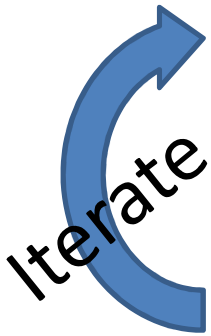


All motor manufacturers supply Speed/Torque curves

Suggestions for selecting a motor

For FRC

1. List everything you want your robot to do
2. Estimate/calculate the torque and speed needed for each function
   - High, Medium, Low, or Intermittent power estimates
     - » Calculate motor torque at rotational speed required
3. From the available motors select one for each function
4. Find (or design) a suitable gearbox to get the best performance from your motor
5. Calculate the load on the motor using this gearbox to insure reliable operation



Like every other aspect of engineering, motor selection is a tradeoff.

What Motors are Available?

2011 FRC Kit of Parts

RS395

RS540

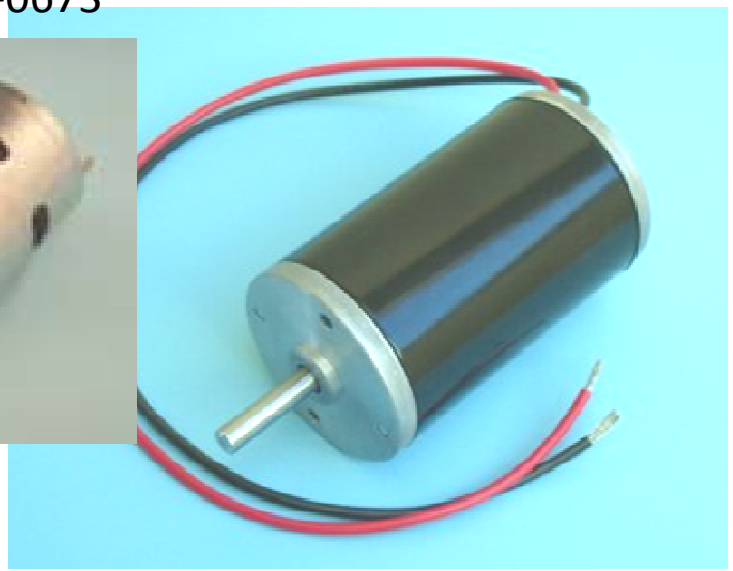
RS550

Fischer Price -0673

Denso - Left

Denso - Right

RS775



CIM

FRC Motor Speed-Torque Data

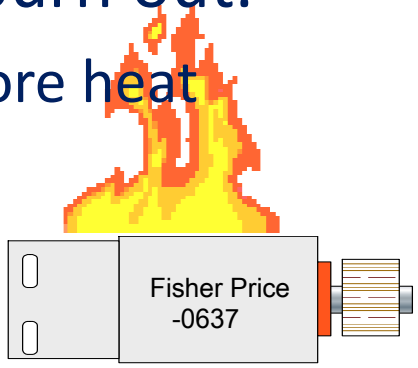
- 2011 FRC Kit of Parts motors

Make	Model	Max Power (W)	Stall Torque (oz-in)	Free Speed (rpm)	Free Current (A)	Stall Current (A)
BaneBots	RS395	48.05	16.65	15500	0.5	15
BaneBots	RS540	123.49	39.48	16800	1	42
BaneBots	RS550	253.52	70.55	19300	1.4	85
BaneBots	RS775	83.05	61.1	7300	1.1	30
CIM	FR801-001	340.11	344	5310	2.7	133
Denso	262100-3030 (Right)	23.48	1501.1	84	1.8	18.6
Denso	262100-3040 (Left)	23.48	1501.1	84	1.8	21
Fisher Price	00801-0673 (2011)	291.59	75.4	20770	0.82	108.7

- 2011 rules allowed use of up to 11 motors
  - Up to 4 CIM motors
  - Up to 4 of any mixture of BaneBots motors (example (3) RS540 and (1) RS775)
  - Two Denso window motors
  - One Fisher Price motor
  - *As many Servos as you want.*

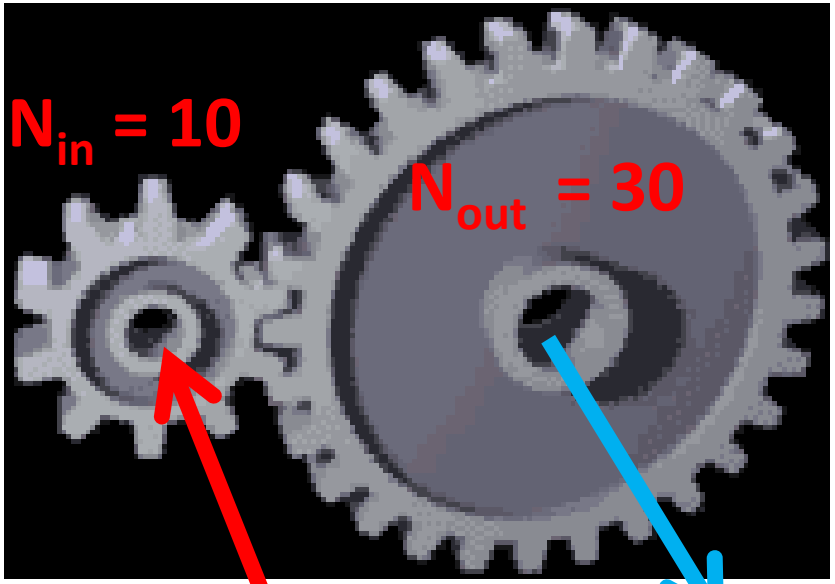
Motor usage

- Small FRC motors have an internal fan and are designed to be operated at higher speeds allowing the heat generated in the motor to be removed (typically find these in cordless drills)
  - Watch out for stall conditions…..If you put too much heat in a motor winding it will burn out.
    - Size matters – larger motors dissipate more heat



Gearing (aka Transmissions, Gearbox)

- A gearbox is used to convert high-speed, low-torque motor output into a lower speed, higher torque output.



Speed Output = Speed Input x N_{in}/N_{out}
Torque Output = Torque Input x N_{out}/N_{in}

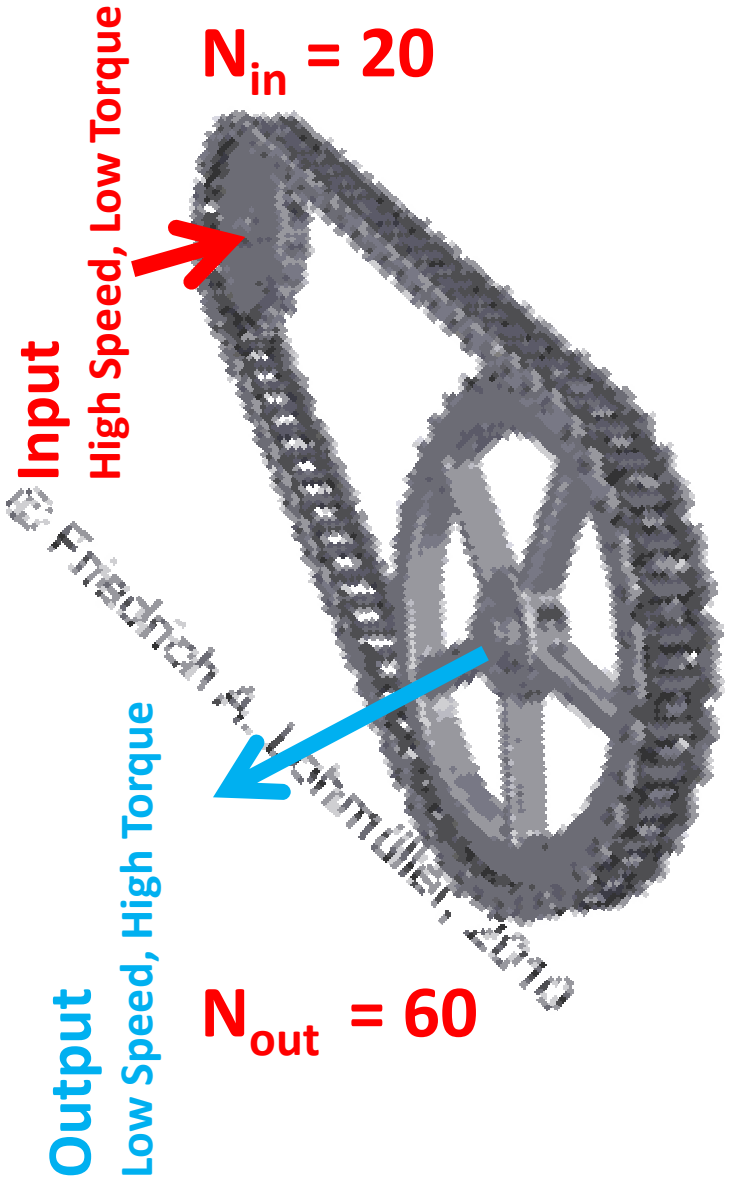
Where N_{in} = # teeth on input gear
N_{out} = # teeth on output gear

Input (from motor)
High Speed, Low Torque

Output
Low Speed, High Torque

With these gears
1/3 the Speed
3X the Torque

Chain Gearing



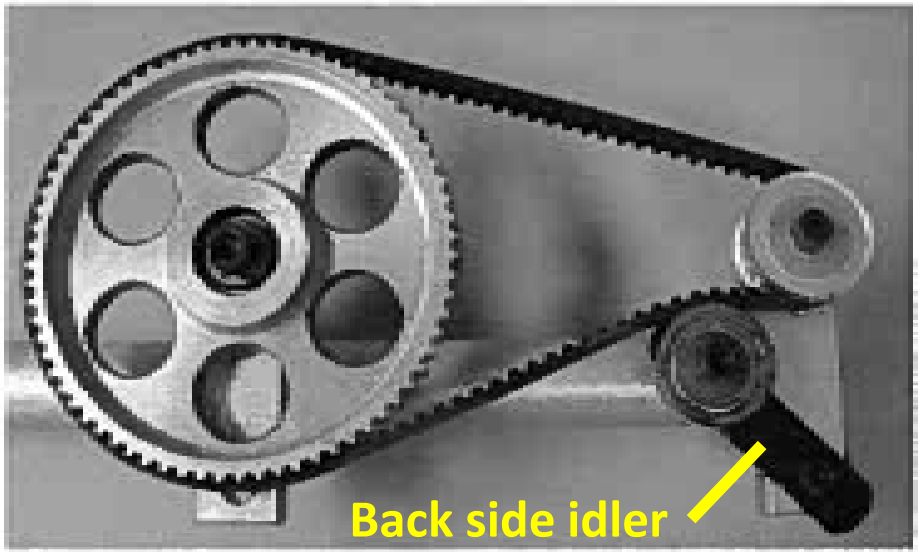
Chain and sprockets operate with the same principals as gears

- Steel and aluminum sprockets available in every size imaginable in standard shaft sizes, (1/4", 3/8", ½", 5/8", ¾",….) and for mounting to hubs
- Maximum gear reduction in a single stage normally about 5:1
- Two sizes of chain/sprockets typically used in FRC
  - #35 – most common, high strength, tolerant of some misalignment, heavier
  - #25 – lighter weight; align well, watch out for shock loads
- Can lengthen/shorten easily
  - Master link (connects chain)
  - Half link (adds ½ pitch of chain length)
  - Buy a chain breaker to cut chain to right length (~ $15)
- Try to engage at least 50% of the sprocket with chain and provide method to tighten chain
  - Chain/sprockets will stretch and wear with use

Belt “Gearing”

- Belts and sprockets will be supplied in the 2013 kit of parts for the kit drivetrain
  - Toothed flat belts operate just as chain with:
    - Lighter weight
    - Less retensioning required

- ✓ Keep belts tight to insure they cannot climb out of sprocket
- ✓ Engage at least 6 teeth
- ✓ Verify alignment of sprockets



Visit www.gates.com/drivedesign
Download the *Light Power and Precision Drive Design Manual* or *Industrial Power Transmission Solutions Catalog*
- Evaluate new drive designs using the *Design Flex Pro* software

FRC Drivetrain Reference Tables

Varying Kitbot Speed by Changing Wheel Sprockets

CIM Motor with KOP (1:12) Transmission				
Transmission Sprocket	Wheel Sprocket	4" Wheel	6" Wheel	8" Wheel
15 tooth	24 tooth	4.05 ft/sec	6.07 ft/sec	8.1 ft/sec
15 tooth	28 tooth	3.47 ft/sec	5.21 ft/sec	6.94 ft/sec
15 tooth	30 tooth	-	4.86 ft/sec	6.48 ft/sec
15 tooth	36 tooth	-	4.05 ft/sec	5.4 ft/sec
15 tooth	40 tooth	-	3.64 ft/sec	4.86 ft/sec
15 tooth	44 tooth	-	-	4.42 ft/sec
15 tooth	48 tooth	-	-	4.05 ft/sec

Note: KOP Transmission comes with a 15 tooth output sprocket standard.

	Coefficient of Friction	Maximum Robot Pushing Force (lbs)	
		100% Weight on Drive Wheels	50% Weight on Drive Wheels
Skyway Wheelchair Wheels:	0.8	118.4	59.2
FRC KOP-Wheels:	1.0	148	74
IFI Traction Wheels - Wedgetop Tread:	1.2	177.6	88.8
IFI Traction Wheels - Roughtop Tread:	1.3	192.4	96.2

Pushing Force = (Wheel Coeff of Friction) x (Weight on Drive Wheels)

Robot Current Draw under Max Drivetrain Load:

The tables below show the amount of current a robot's motors will draw in their maximum loaded configuration. (Pushing against a wall).
In the example below, it is assumed the drivetrain is 90% efficient, and the robot weighs 148 lbs (120 lb robot + 13 lb battery + 15 lb bumpers).
COF = Coefficient of Friction, (Skyway Wheelchair Wheels = 0.8, FRC-Kit of Parts Wheels = 1.0, IFI Roughtop Wheels = 1.3)

2x CIM Motor Drivetrain

50% of Robot Weight on Driven Wheels

Robot Speed (ft / sec)	Current Draw per Motor (Amp)		
	0.8 COF	1.0 COF	1.3 COF
2	10.4	12.4	15.5
2.5	12.4	15.0	18.8
3	14.5	17.5	22.1
3.5	16.5	20.0	25.4
4	18.5	22.6	28.7
4.5	20.6	25.1	32.0
5	22.6	27.7	35.3
5.5	24.6	30.2	38.6
6	26.6	32.7	41.9
6.5	28.7	35.3	45.2
7	30.7	37.8	48.4
7.5	32.7	40.3	51.7
8	34.8	42.9	55.0
8.5	36.8	45.4	58.3
9	38.8	47.9	61.6
9.5	40.8	50.5	64.9
10	42.9	53.0	68.2
10.5	44.9	55.5	71.5
11	46.9	58.1	74.8
11.5	49.0	60.6	78.1
12	51.0	63.2	81.4
12.5	53.0	65.7	84.7
13	55.0	68.2	88.0
13.5	57.1	70.8	91.3
14	59.1	73.3	94.6
14.5	61.1	75.8	97.9
15	63.2	78.4	101.2

2x CIM Motor Drivetrain

100% of Robot Weight on Driven Wheels

Robot Speed (ft / sec)	Current Draw per Motor (Amp)		
	0.8 COF	1.0 COF	1.3 COF
2	18.5	22.6	28.7
2.5	22.6	27.7	35.3
3	26.6	32.7	41.9
3.5	30.7	37.8	48.4
4	34.8	42.9	55.0
4.5	38.8	47.9	61.6
5	42.9	53.0	68.2
5.5	46.9	58.1	74.8
6	51.0	63.2	81.4
6.5	55.0	68.2	88.0
7	59.1	73.3	94.6
7.5	63.2	78.4	101.2
8	67.2	83.4	107.8
8.5	71.3	88.5	114.4
9	75.3	93.6	121.0
9.5	79.4	98.7	127.6
10	83.4	103.7	134.1
10.5	87.5	108.8	140.7
11	91.5	113.9	147.3
11.5	95.6	118.9	153.9
12	99.7	124.0	160.5
12.5	103.7	129.1	167.1
13	107.8	134.1	173.7
13.5	111.8	139.2	180.3
14	115.9	144.3	186.9
14.5	120.0	149.4	193.5
15	124.0	154.4	200.1

4x CIM Motor Drivetrain

50% of Robot Weight on Driven Wheels

Robot Speed (ft / sec)	Current Draw per Motor (Amp)		
	0.8 COF	1.0 COF	1.3 COF
2	6.4	7.4	8.9
2.5	7.4	8.6	10.5
3	8.4	9.9	12.2
3.5	9.4	11.2	13.8
4	10.4	12.4	15.5
4.5	11.4	13.7	17.1
5	12.4	15.0	18.8
5.5	13.5	16.2	20.4
6	14.5	17.5	22.1
6.5	15.5	18.8	23.7
7	16.5	20.0	25.4
7.5	17.5	21.3	27.0
8	18.5	22.6	28.7
8.5	19.5	23.9	30.3
9	20.6	25.1	32.0
9.5	21.6	26.4	33.6
10	22.6	27.7	35.3
10.5	23.6	28.9	36.9
11	24.6	30.2	38.6
11.5	25.6	31.5	40.2
12	26.6	32.7	41.9
12.5	27.7	34.0	43.5
13	28.7	35.3	45.2
13.5	29.7	36.5	46.8
14	30.7	37.8	48.4
14.5	31.7	39.1	50.1
15	32.7	40.3	51.7

4x CIM Motor Drivetrain

100% of Robot Weight on Driven Wheels

Robot Speed (ft / sec)	Current Draw per Motor (Amp)		
	0.8 COF	1.0 COF	1.3 COF
2	10.4	12.4	15.5
2.5	12.4	15.0	18.8
3	14.5	17.5	22.1
3.5	16.5	20.0	25.4
4	18.5	22.6	28.7
4.5	20.6	25.1	32.0
5	22.6	27.7	35.3
5.5	24.6	30.2	38.6
6	26.6	32.7	41.9
6.5	28.7	35.3	45.2
7	30.7	37.8	48.4
7.5	32.7	40.3	51.7
8	34.8	42.9	55.0
8.5	36.8	45.4	58.3
9	38.8	47.9	61.6
9.5	40.8	50.5	64.9
10	42.9	53.0	68.2
10.5	44.9	55.5	71.5
11	46.9	58.1	74.8
11.5	49.0	60.6	78.1
12	51.0	63.2	81.4
12.5	53.0	65.7	84.7
13	55.0	68.2	88.0
13.5	57.1	70.8	91.3
14	59.1	73.3	94.6
14.5	61.1	75.8	97.9
15	63.2	78.4	101.2

Legend: Under 40A Breaker Limit | Risk of Popping Breakers | Outside Safe Zone

Gearbox Options for FRC

- AndyMark www.andymark.com
  - Lot's of alternatives for CIM motors
    - Single and multi-speed
    - CIM adapters for F-P and RS motors
- Banebots www.banebots.com
  - CIM motor gearboxes
    - CIM adapters for RS motors
  - RS motor gearboxes
  - Must order early - lead times typically 2 to 3 weeks
- Robot MarketPlace www.robotmarketplace.com
  - Can order complete motor/gearboxes
    - Remove and use KOP motor
      - Need a pinion gear puller
    - RS540, 550, 775 motor/gearboxes
- Build your own??
  - Fisher Price gearboxes available from F-P service centers
    - Be sure to buy wheel adapter to make interface easier
    - Spare motors only available at Andymark
  - Salvage gearbox from cordless drills
    (NBD – Nothing But DeWalt)
    - Instructions for DeWalt modifications on Chief Delphi

Other FRC Resources

- Your best resource is other FRC teams
  - Most teams have websites with contact info
    - and they all want to make you successful -
- Visit Chief Delphi (www.chiefdelphi.com)for white papers, good practices, discussions, …..
  - Things ~~new~~ teams should read
    - Large cantilevered loads on gearboxes
    - Carpet to wheel coefficient of friction
    - Use of #35 and #25 chain
    - Worm gears, planetary gears, spur gears
    - Alignment, Alignment, Alignment
    - Belts, cables