Team 968/254 Lifting Arm Calculation
2010 FRC Breakaway
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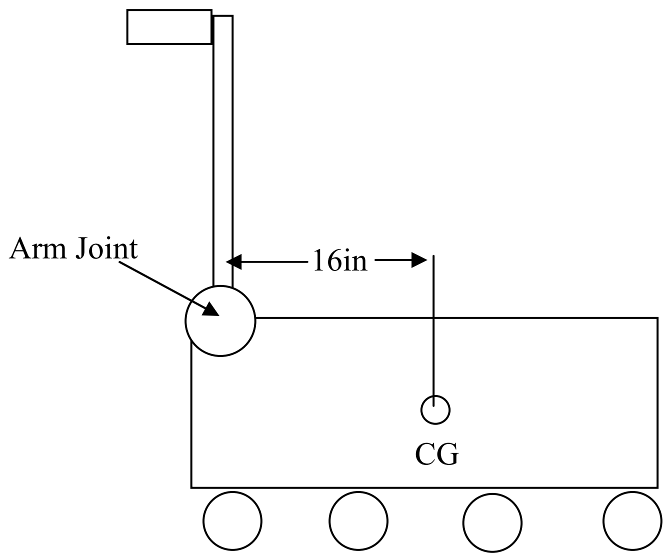
Assumed Configuration:



For the robot weight, 150 lbs is assumed, located at the CG.
Assuming the CG is 16” from the lifting arm, and that nothing supports the robot other than the moment (torque) about this arm joint, then 200 lbf-ft of torque is needed at this joint to *just begin* to rotate the robot. This is the point in time when the normal force on the wheels would *just* become zero. To actually accelerate the robot into motion beyond this point, obviously a bit more torque would be needed, for a short period of time. We’ll consider this point later.

One CIM motor has a stall torque of 2.22 Newton-Meters, which is equivalent to 1.622 lbf-ft. For four CIM motors, we would have a stall torque of 1.622*4 = 6.488 lbf-ft. (at the motors, before any gearing).

The stall current of each CIM is 133 Amps. We want to be drawing something like 30A during normal lifting conditions, to avoid tripping circuit breakers. So, we take our ratio of desired current draw to stall current, and multiply it by the stall torque, to achieve our operating torque.

30A/133A * 6.488 lbf-ft = 1.463 lbf-ft operating torque (at the motors, before any gearing).

Now, let’s multiply through by our gearbox ratios to determine the torque on the PTO shaft. We’ll assume the PTO shaft is driven 14 tooth to 64 tooth for the greatest reduction possible within the gearbox.

1.463 lbf-ft * 45/12 *64/14 = approximately 25 lbf-ft of operating torque (within current limits) out of the gearboxes (both gearboxes together, 4 CIMs)

In our initial calculation, we determined 200 lbf-ft was needed to *just begin* to lift the robot off the ground. **With 4 CIMS, and a 14 tooth to 64 tooth PTO drive,** we calculated that we had approximately 25 lbf-ft of torque available at 30 Amps per motor. Thus, with this configuration, **an additional external reduction of 8:1 or greater would be required.**

Now, **suppose we wished to drive the arm from the 30 tooth to 48 tooth PTO drive**, to avoid purchasing and machining more 64 tooth gears. The difference in ratios in the gearbox is (64/14) / (48/30) = approximately 2.85:1 difference. So, if we were to drive the arm from this "high gear side" 48 tooth PTO, an additional reduction of the 8:1 calculated above, and another 2.85:1 would be needed. Hence, **a total additional/external reduction of 22.8:1 or greater would be required.**

It would be advisable to utilize a reduction slightly lower (numerically higher) than those listed above, for the purposes of accelerating the robot through the lifting operation.

How long will it take to rotate the robot 90 degrees to lift it off the ground?

The torque required is not at all constant. The most torque is needed when the robot is in the horizontal position. But, for the sake of some quick rough numbers, let's assume this torque is constant for the entire lifting operation, during which the robot rotates 90 degrees relative to the ground.

In the scenario above, the motors are operating at 30 Amps, which is 22.5% of the stall torque, or 77.5% of the no-load speed. Let's run through the reductions, and determine the angular speed of the arm.

5300 RPM (no load) * 0.775 (loaded speed ratio) * 12/45 * 14/64 * 1/8 = 30 RPM or, 2 seconds per full 360 degree rotation. Thus, **it would take approximately ½ second to rotate the 90 degrees required to lift.**

In reality, it would probably be quicker than this, because as mentioned above, the torque requirement decreases through the lifting operation due to the CG moving closer to the arm joint in the horizontal plane.

So, a lower (greater numerical) reduction could be implemented, for finer control, since there is sufficient power to make the lifting operation plenty-quick.

It is quite possible that the lifting operation may be sufficiently completed even using only two CIMS (one side of the drive), however a greater external reduction (16:1 or higher) would be required, and the lifting speed would of course be only half as fast.