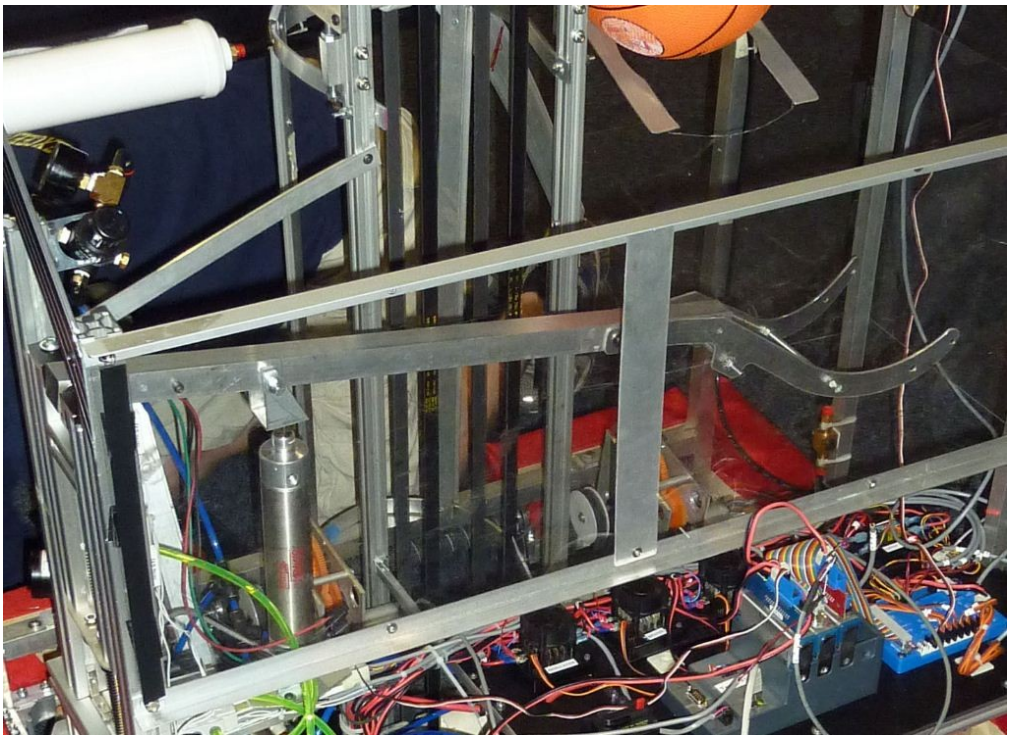
FRC Adjustable Pressure System

A basic FRC pneumatic system operates at a fixed working pressure, typically 60psi.
It's also easy to arrange for multiple manually fixed working pressures by adding more secondary regulators, but something more is required to be able to change pressures from the driver station on-the-fly.
So, how do we get pneumatic pressure that's adjustable on-the-fly during match play?

Team 358's pneumatic catapult in 2012 had several dynamic adjustments to range and arc, a principal adjustment was to the pressure powering the arm cylinder seen in the photo below. The pressure adjustment was remotely controlled by one of the human drivers aided by Dashboard pressure readouts and increased/decreased using a joystick on an xbox controller.



Some imposed limitations:

- FRC pneumatic rules typically allow 120psi storage pressure, but limit working pressure to 60psi or less. So the adjustable part of the system must not, under any circumstances be able to surpass 60psi. The easiest way to guarantee this is to spin the adjustable pressure section off of a 60psi regulated section. The upper limit of 60psi is enforced by the fact that the supply pressure at this point was already manually limited to 60psi. The adjustment cannot accidentally open the regulator to more than 60psi.

- To insure safety, pneumatic parts must be commercially rated for >120psi and must not be physically altered or modified in any way.

- Solenoid pneumatic valves require a minimum working pilot pressure typically 20-30psi, otherwise the valve will not operate properly and become stuck or ineffectively leak air.

So our adjustable pressure was designed for a variance between 30 and 60 psi.

Component Parts & Assembly

The pressure adjusting system needs several parts:

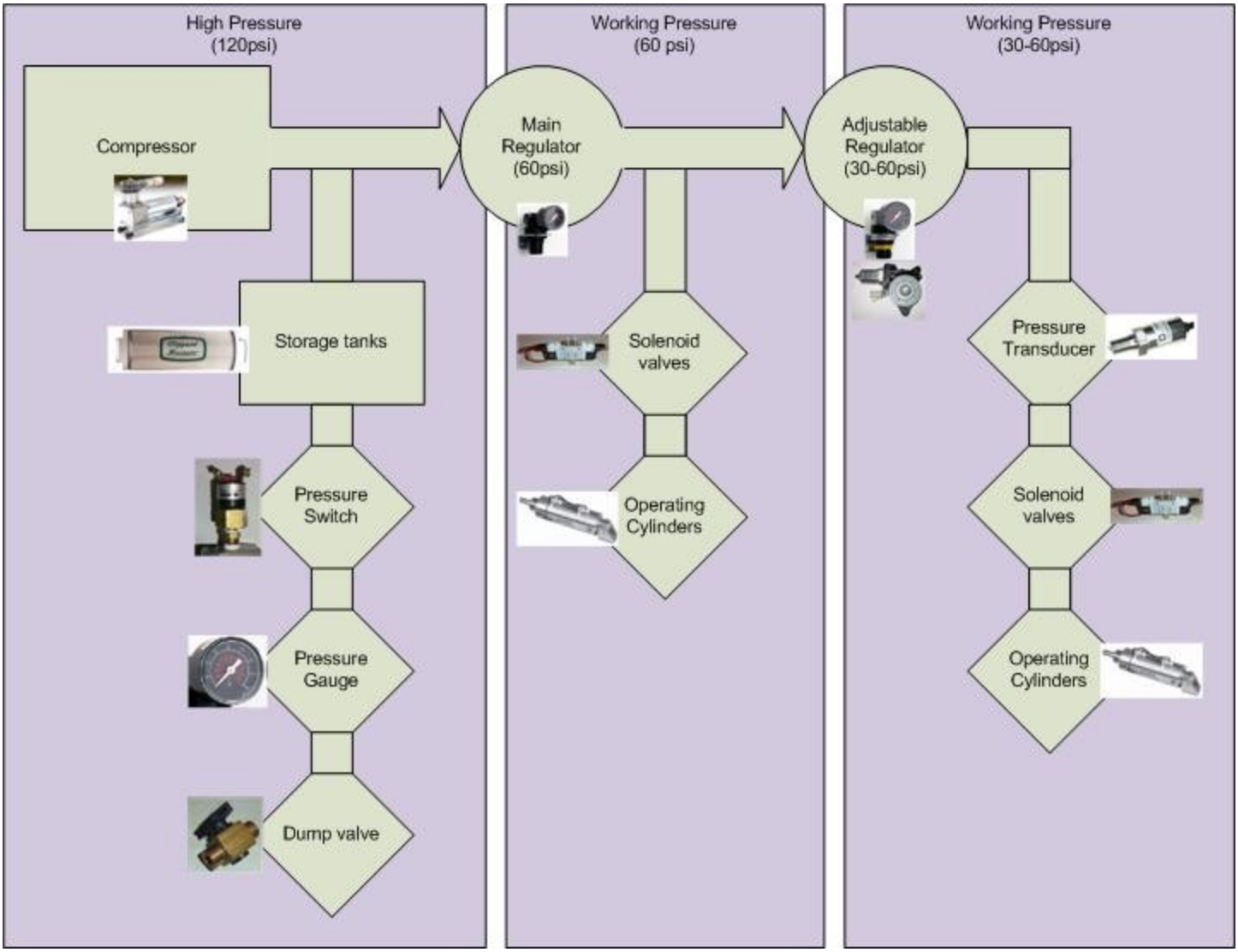
- Pressure transducer to give feedback on the current pressure. This is an analog device and the reading needed to be converted to psi for our use. For the conversion we took analog readings every 5psi by pressure gauge, then determined a best fit calculation (http://en.wikipedia.org/wiki/Curve_fitting), e.g., psi = analog-reading*29.54-10.41 (psi= analog-reading *slope + y-intercept). The best curve fit can be calculated in Microsoft Excel using the LINEST function and a series of measured points (analog output/pressure gauge reading). For LINEST highlight two cells and SHIFT/CTRL+ENTER to get both the slope and the y-intercept.

Just one example:
http://www.team358.org/files/pneumatic/PressureTransducer-SSI-Specs.pdf

- An adjustable Kit-of-Parts (KOP) secondary pressure regulator (top of right photo). At the bottom this has a yellow locking ring that must be disengaged, and a black knob that twists to adjust the pressure. Our goal is to adjust this knob using a motor. Caution needs to be taken not to turn the adjusting knob to hard/far and break it. That means training the driver, or having a software safety that stops if no pressure change is being detected.

- A window or other FRC legal motor to drive the adjustment (bottom of right photo). This is setup to be controlled by the driver or tuning software.

- A coupling tube between the window motor and the regulator and hose clamps to fasten it in place (middle of right photo). You just need a way to grip the regulator knob and you want to be able to easily replace the regulator and motor if necessary. We found a tube of the correct diameter, mounted the motor facing the regulator knob, and connected them. Presetting the regulator to a known pressure to start can be helpful.



120psi high-pressure -> 60psi regulated working-pressure -> 30-60psi regulated adjustable-pressure

Operation:

Pressure can be adjusted directly by one of the human drivers or a driver can specify target pressures and let software feedback make the adjustment. It just depends on the amount of automation and complexity you want. The pressure transducer sensor provides feedback for pressure in the range of 0 to 60psi, and the driver just controls the window motor movement. The window motor speed can be slaved to a joystick or controlled some other way the driver feels comfortable with.

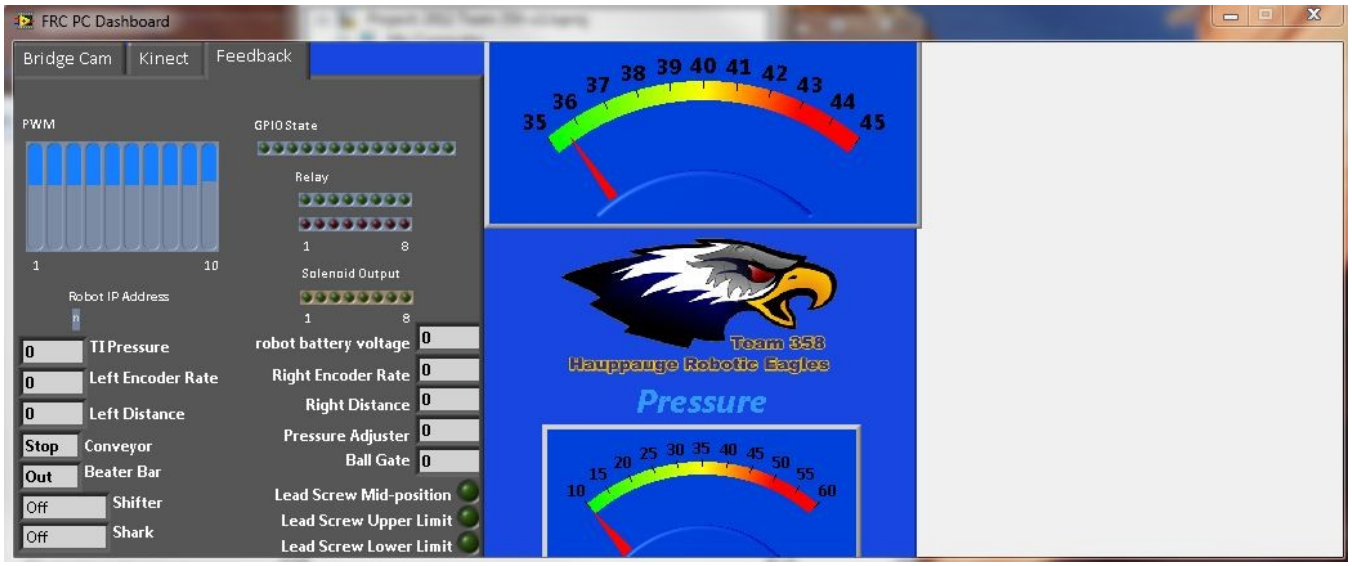
The pressure feedback can be visual, allowing the drive to manually adjust the pressure, or used to feed software feedback control, such as PID. In either case you must insure that:

1. The software or human driver protects against run-away adjustment, e.g., the software stops the motor if it's turning, but no corresponding pressure change is detected. The danger is the software may chase unreachable target pressures and over-turn the regulator knob, thus damaging it.

2. The target pressure is reachable, e.g., if the primary regulator gets reset to 58psi, then the subordinate adjustable regulator will never be able to reach 60psi. In the other direction, the pressure transducer may never quite read zero.

3. When the pressure is adjusted downwards there must be a mechanism to bleed excess pressure, so the adjustable pressure actually drops.

In this operator display the bottom gauge reflects the full range (0-60psi) of the working pressure allowed by FRC rules. The top pressure readout is simply a detail of the effective operating range for our catapult (35 to 45psi).



Notes:

- For this catapult application the pressure adjustments being made were in the range of half a pound per square inch. Less than this there was some small variance in how the regulator responded.

- Adjustment was responsive when increasing the pressure. The higher pressure took little time to bleed in.

- Lowering the pressure required another mechanism for dumping some air. The regulator would not automatically bleed over-pressurized air. This could be accomplished with an additional solenoid to dump a minimum amount of pressure by turning on/off very quickly, or by operating an existing mechanism, in this case dry firing the catapult. The pressure drops, then climbs back up to the target quickly enough.

- The upper pressure limit of 60psi is dependent on the primary regulator setting. It can be set to less than 60psi and in practice since it is originally set manually the pressure is +/- a psi or two.

- Carefully avoid over driving the adjustable knob on the pressure regulator. Too many turns can damage or just disconnect it.