Servo Power Feed for Lathe

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My first lathe was a Logan with change gears. What a nuisance change gears are. Because of that I only used them when I had to, for threading. Never for feeding. My current lathe is a Jet, with a QC gear box. But I never used them for feeding either. Rather than look up the feed setting, change the gears and diddle with the forward-reverse gear (and do it all over again if the feed wasn't what I wanted), I just fed by hand.

I have a VFD on my drill press and that was the kind of control that I wanted for the lathe feed. Not literally a 3 phase motor and VFD - but that degree of flexibility. What I went for was a DC motor, with a tach servo amp. The tach feedback gives excellent feed consistency, while the controller allows feed adjustment with the twist of a knob (even while turning). That's as good as it gets, this side of CNC.

My first issue was pinning down what the feed shaft* would need in terms of speed (RPM) and torque. The speed range minimum is for doing fine feeds with low spindle speed (large diameter work & low FPM), and the maximum for doing rough cuts at high spindle speeds (small work & high FPM). The math is in the appendix and the range I figured was 2.5 - 900 RPM. I determined the maximum torque required by setting up a heavy cut and driving the feed shaft with a cordless drill. I adjusted the drill's clutch to just slip on the maximum cut and measured that torque on the bench. It was 15 in-lb.

I had a small PMDC motor in my junk pile, but it had no name plate so I didn't know it's operating specs. Speed wasn't much of a problem - unless you want to run it pretty fast (in excess of 5000 rpm), most small PMDC motors will run in a wide range. I already had my servo amp, which uses a minimum of 40v, so I applied 40v to the motor and measured 3000 rpm. Good - that would pulley-down to 900 nicely.

Torque was a bigger question - how much torque would the motor produce with the 12.5 amps that the servo amp could supply and would it overheat at that current. So I applied 12.5 amps to the motor, in a locked rotor condition and measured the torque. It was 15 in-lbs. Wow - exactly what I needed. And given that it would be pulleyed-down 3.3:1, the feed shaft torque would be 50 in-lbs. Plenty of margin. As to the heat, I left it locked rotor and measured the resistance as it cooked. After 15 min the resistance had increased 10%, well below the 30% that would occur at the 100 degree C limit.

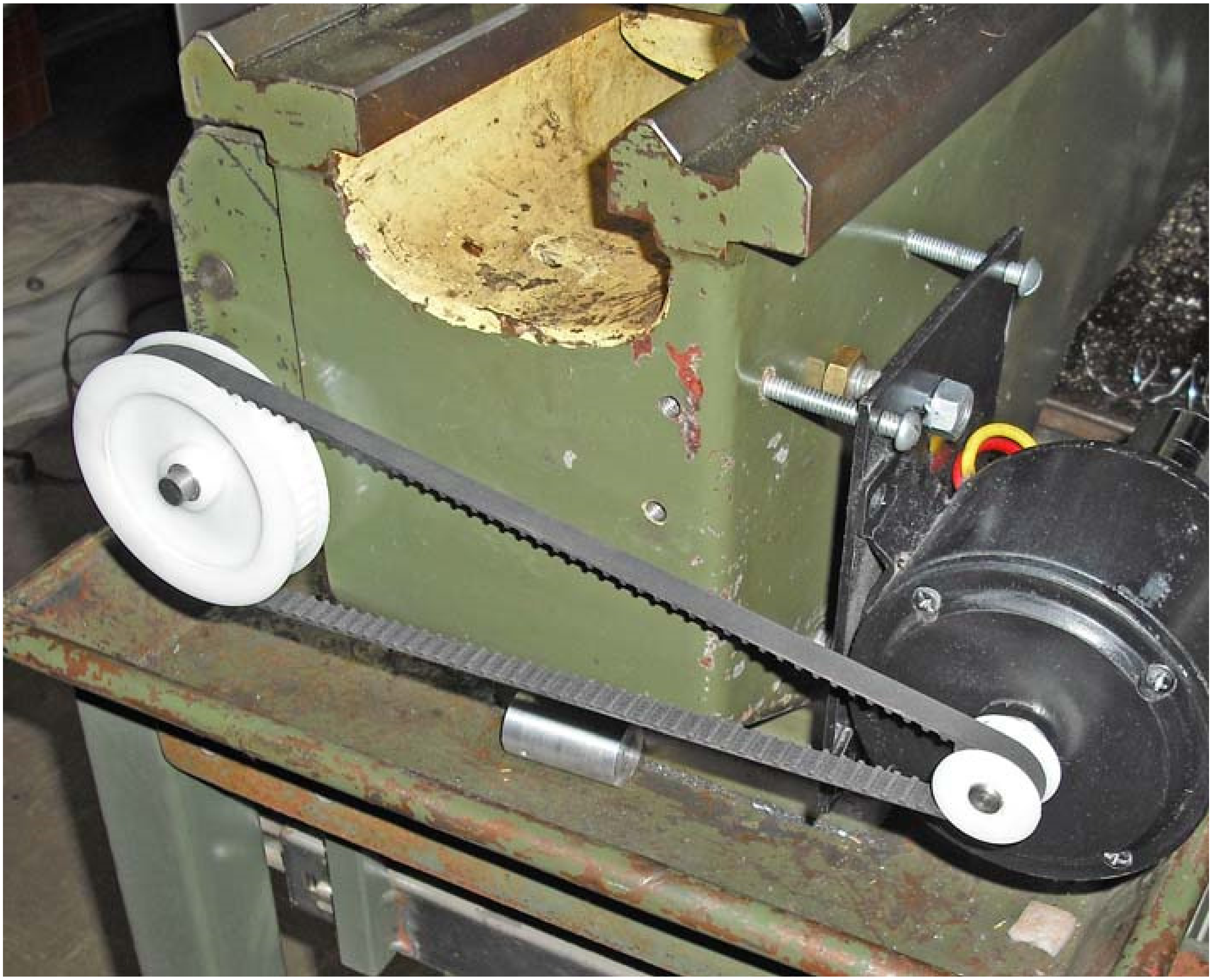
* - My lathe has a lead screw for threading and a shaft-with-keyway for feeding. It's this feed shaft that I'm driving with the servo

The basic configuration is a pulley on the end of the feed shaft, driven by a motor mounted on the back of the lathe, and connected by a belt.

The end of the feed shaft is flush with its mounting. To mount a pulley on it I removed the shaft and bored a hole to accept an adapter I made. The adapter is pinned to the feed shaft.

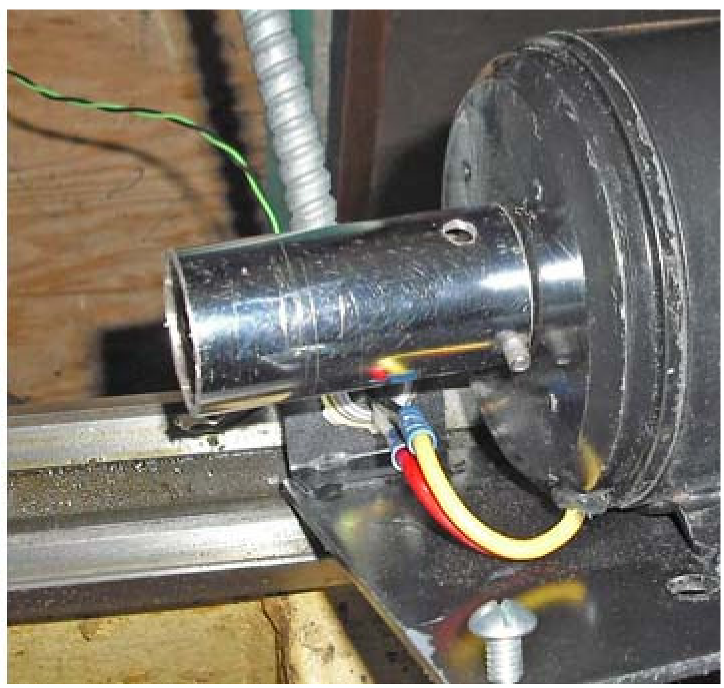
The pulleys are acetal. They and the belt are from McMaster-Carr. "XL" size timing belt. If the tool jams, the belt jumps over the cogs in the pulley, so nothing breaks.

The motor mount allows belt tensioning and vertical and horizontal rotation to align the pulleys.



The motor had a single-ended shaft. So I took the rotor out, bored and tapped the blind end, and made an adapter to drive the tach. And drilled a hole in the end cover.

The tach is a small PMDC motor. A Maxon brand - well regarded for low ripple. I had scavenged a few other small motors, including one that was the capstan drive on a cassette tape deck. The tape deck one probably would have been good enough, but I bought the Maxon just to be on the safe side.



I used a piece of 1" chromed tube as a housing for the tach. More to protect the tach than support it.

Yet another MOT put into service. I cut the welds and removed the secondary. Then I took a primary from another MOT and removed enough turns to give me 40v when used as a secondary. Welded back together and wedged some shims in place to reduce hum ("reduce", not "eliminate").

The servo amp can use power from 40 - 190v, unregulated. But "unregulated" does not mean unfiltered. The maximum ripple is 25v, meaning that a substantial capacitor was required. I used a 10,000ufd, cause that's what I had and it gives about 10v ripple full load.

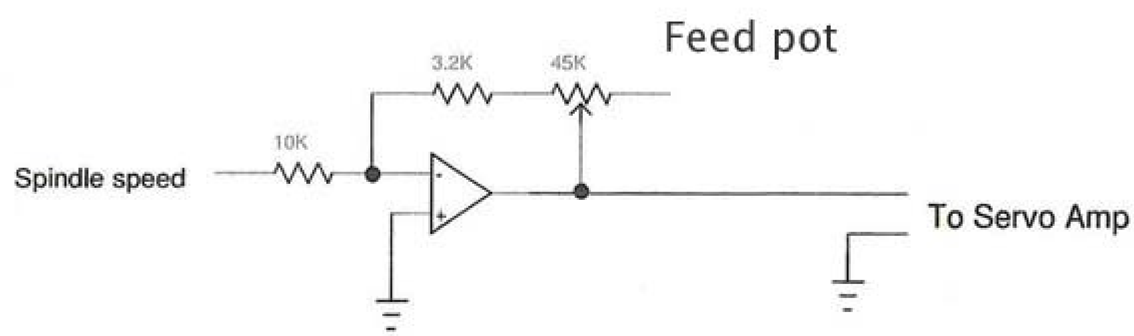
The servo amp mounted on an electrical junction box that holds the transformer, bridge, and cap.

Here's the part that I think is the most interesting. Controlling a spindle's speed is straight forward: a pot can be calibrated in RPM. A feed shaft control is more complicated: the feed shaft speed depends upon the feed rate and the spindle speed. But if you know the spindle speed, then:

feed shaft speed = feed * spindle speed / feed shaft pitch

(by "feed shaft pitch" I mean the distance that the carriage advances for one turn of the shaft.)

In itself this isn't very useful, but if you have a signal representing the spindle speed (e.g., a tach output), then this calculation can be made with an op amp, giving a signal that controls the servo amp. The operation here is trivially simple: the gain in the circuit is the ratio of the feedback resistance to the input resistance. See the appendix for the calculation of the values.



Now, about the spindle speed signal: it isn't really a tach output, but a signal from a controller that I use for my spindle VFD. More about that in another post.

The "Forward" switch is on-off-on, allowing "Reverse" if I find I want it. I doubt that I will. "Rapid Reverse" is full speed (.6 ips) reverse, overriding the "Forward" setting. I put it in thinking that it might be useful for returning after a long cut. I don't use it much for that, but it is useful as a instant way to stop and back away from a shoulder. More crisp than disengaging the apron lever. Also better when you overshoot a touch and need to back off, fast. The feed is only enabled when the spindle is turning.

I did the layout/graphics with DeltaCAD, printed it mirror image on transparency "paper", and glued it to the controller panel. Printing it mirror image puts the printing on the back and protects it from wearing off.

I need to use a project a while before I know how good it is. Sometimes great ideas don't turn out all that well. I've used the feed control and it is all that I expected it to be - it works great! The ability to just turn it on and dial in the feed means that I rarely hand feed anymore, with better results. And it is so quiet! Maybe my lathe is clapped out, but the change gear train is noisy. Not the DC motor, timing belt, and acetal pulleys. Not only is it convenient, it works very well: the feed is very accurate and the servo rock solid (does not bog down under heavy loads).

What did it cost? Well, the motor was scrounged (but All Electronics has them for about $20). The servo amp was $26 (eBay and a good deal) and the tach $18 (eBay again). The transformer, bridge, and cap were from my junk pile. The pulleys and belt were $26 (McMaster Carr). The elex were mostly from the junk pile, plus a few bucks for bought parts. You could probably scrounge or make everything but the servo amp, or you could buy everything for maybe $125.

Appendix

Determining feed shaft speed requirements

The minimum feed shaft speed is for doing a fine cut on a large piece at low FPM. The values are .003 feed, 10" diameter, and 80 FPM. The spindle speed would be 30 RPM (FPM * 12 / PI * diam). Then:

feed shaft speed = feed * spindle speed / feed shaft pitch
= .003 * 30 / .040
= 2.25 RPM

The maximum speed would be for doing rough cuts on small work at high FPM. Here the actual diameter and FPM are irrelevant since my maximum spindle speed is 2200 RPM. Then:

feed shaft speed = feed * spindle speed / feed shaft pitch
= .050 * 2200 / .040
= 2750 RPM

But this gives a carriage speed of 1.83 IPS, which is too scary for me. So I decided to limit it to .6 IPS, which is a feed shaft speed of 900 RPM. This means that at high spindle speed and high feed rates the actual feed may be "clipped" (less than dialed in).

Op Amp Circuit Calculations

From

feed shaft speed = feed * spindle speed / feed shaft pitch

it follows

feed shaft speed / spindle speed = feed / feed shaft pitch

and since

feed shaft speed = (servo input * 300) / 3.3

(i.e., the motor is 300 RPM / volt and it's pulleyed down 3.3:1 to the feed shaft. Giving 90.9 RPM / volt overall) and

spindle speed = spindle tach signal * 350 (i.e. 350 RPM / volt)

then

servo input * 90.9 / spindle tach signal * 350 = (.003 to .050) / .040
servo input/ spindle tach signal = (350 / 90.9) * (.003 to .050) / .040
= .29 to 4.81

But "servo input/ spindle tach signal" is simply the gain of the op amp circuit (the ratio of the output to the input). And the gain is determined by the ratio of the feedback resistance to the input resistance. Picking 10k as the input resistance, the feedback resistance must have the range 2.9k to 48.1k. Make that a fixed resistor of 3k and a pot of 45k (0 to 45).