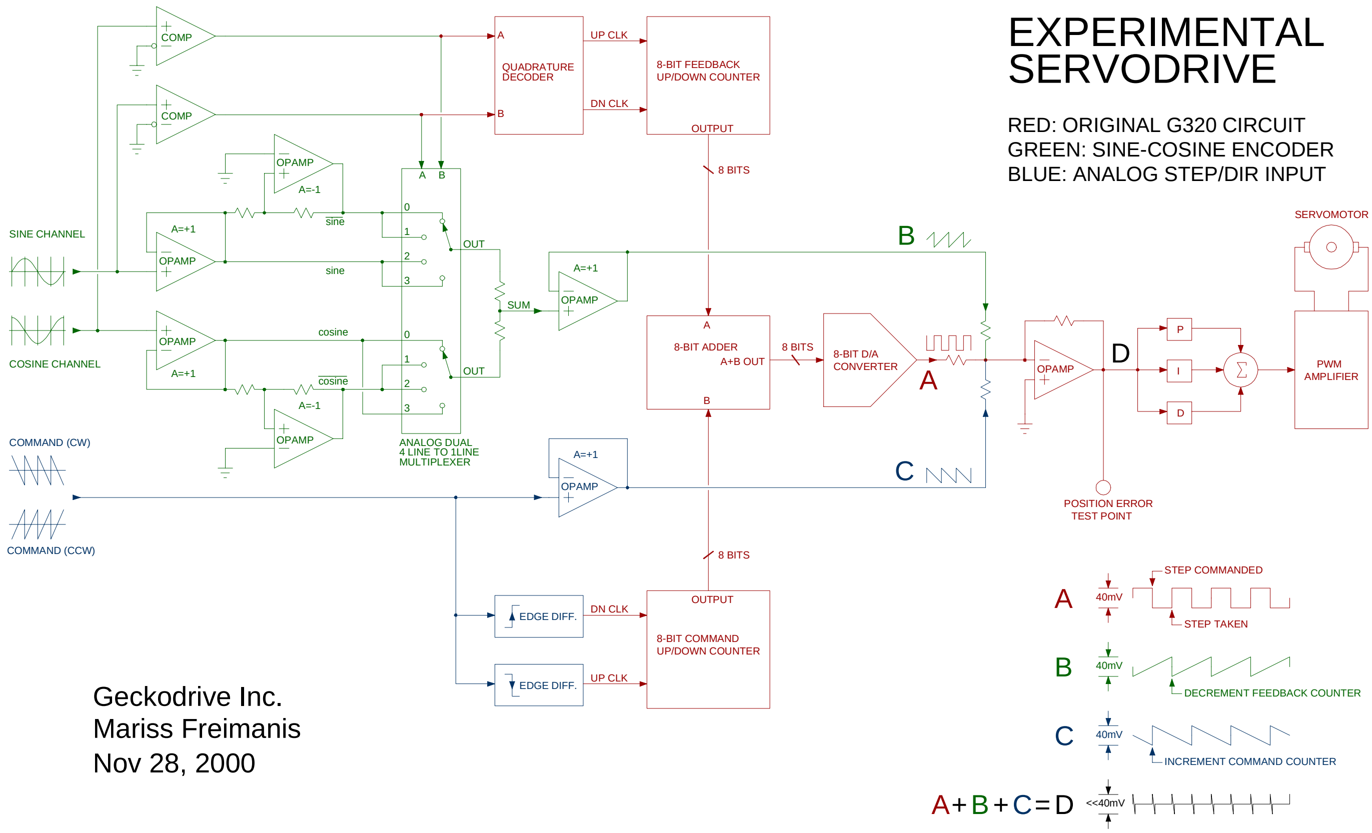
INTERPOLATING SERVDRIVE



CIRCUIT DESCRIPTION:

The circuit shown in red is the existing G320. It functions as a position type PID servo. Step and direction is input to an U/D 8-bit COMMAND COUNTER. The digital quadrature encoder inputs are decoded into clock and direction data that is sent to an U/D 8-bit FEEDBACK COUNTER. The outputs of both counters are summed by an 8-bit ADDER that generates an 8-bit position difference between both counters. The 8-bit D/A CONVERTER then converts this difference to a voltage. This voltage is scaled so that an increment of position error is a 40 mV change. The no position error voltage is 5VDC.

THE PROBLEM:

In normal low-speed operation, a CW step pulse causes the POSITION ERROR voltage to decrease by 40 mV. The PID loop senses the motor is now behind by 1 count, so it makes the motor move CW until the encoder causes a 40mV jump in the voltage. The motor stops because position error has been reduced to zero. See timing graph A. Note the motor moves in incremental “steps” at low speed.

Ideally the motor should be stopped when no steps are sent. Actually the PID integrator will over time multiply the smallest voltage, causing the motor to move. Because a digital encoder gives no feedback between signal edges, the motor will move until it makes the encoder generate an edge. Then motor reverses direction until the other adjacent encoder edge is generated. The motor “dithers” between these two edges. This dithering causes an annoying noise from the motor and also means the motor is vibrating.

DITHERING SOLUTION:

What is needed to stop dithering is an encoder that gives continuous feedback. An analog sine-cosine encoder does just that. Because the encoder has to provide position feedback, it would be good to derive a voltage proportional to position over the span of one increment of motion. The value of sine from –45 degrees to +45 degrees is nearly linear, and the 90 degrees span is one increment of motion. The circuit shown in green derives this voltage for each of the four 90 degree segments that make up one complete encoder cycle.

The 4 op-amps generate +sine, -sine, +cosine and –cosine signals from the encoder inputs. The 2 comparators are set to the zero-crossing voltages of the encoder signals and reconstruct the quadrature signals necessary for the original circuit. The comparator outputs also generate the 2-bit address needed by the dual 4 to 1 line analog multiplexer. The multiplexer selects which two of the four op-amp outputs will be summed for each of the four 90 degree encoder cycle segments. Summing two sinusoids offset by 90 degrees results in a 45 degrees shift. The summed outputs are now the desired voltage proportional to position for each 90 degrees encoder cycle segment. This voltage will look like a saw-tooth waveform when the motor is turning. See timing graph B.

When the drive is stepped at low speeds with the green circuit present, the motor will move until the voltage ramp level nulls the integrator. The motor will now be completely still and silent when stopped. Note that the motor still moves in steps at low speed but now the motion is more damped.

STEP SOLUTION:

Because steps still are sent in an incremental fashion, the servodrive has no choice but step the motor even though it no longer dithers. If the commanded position abruptly changes and then is constant, (stepped) the motor has to do the same.

What if the “step” command also carries continuous position information just like the analog decoded sine-cosine encoder? Symmetry suggests the “step” signal should look like a mirror image of the encoder signal. The circuit shown in blue does just that. A reverse saw-tooth waveform is applied as a command input. It is differentiated to find the fast edge of the waveform. The direction of the fast edge determines if the COMMAND COUNTER is to be incremented or decremented. The waveform is also scaled so it exactly equals the amplitude of the analog decoded encoder signal. Both amplitudes have to be equal to the LSB value of the D/A converter (40 mV). See timing graph C.

The sum of these signals results in a constant voltage, indicating the motor would move smoothly and continuously rather than stepping now. See timing graph D. Furthermore locations between steps can be resolved.

EXPERIMENTAL RESULTS:

The circuit as shown above was breadboarded and first run on Nov 28, 2000. The “step” input waveform was generated by a 12 bit D/A converter driven by a 12-bit U/D counter. This insured a constant amplitude saw-tooth waveform at any frequency. The counter was clocked with a variable frequency function generator and was free to overflow. The encoder on the motor was DRC 100 line quasi sine-cosine encoder. This resulted in 400 counts per revolution. A mirror sliver was glued to the motor shaft and a collimated HeNe laser beam was bounced from this mirror to a wall 24 ft away. The subtended angle of 0.9 degrees resulted in a 9” linear displacement of the laser beam on the wall. The purpose was to see the motor behavior over the span of 1 increment of motion.

The function was set to 7.585 Hz for a rotational speed of 0.1 degrees per minute. A ruler was taped to the wall along the path of the projected laser beam. Measurements of the beam position were taken every 60 seconds. Preliminary show a linearity of better than 5%. Also noted was the extremely smooth nature of the motion. More data to follow.

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