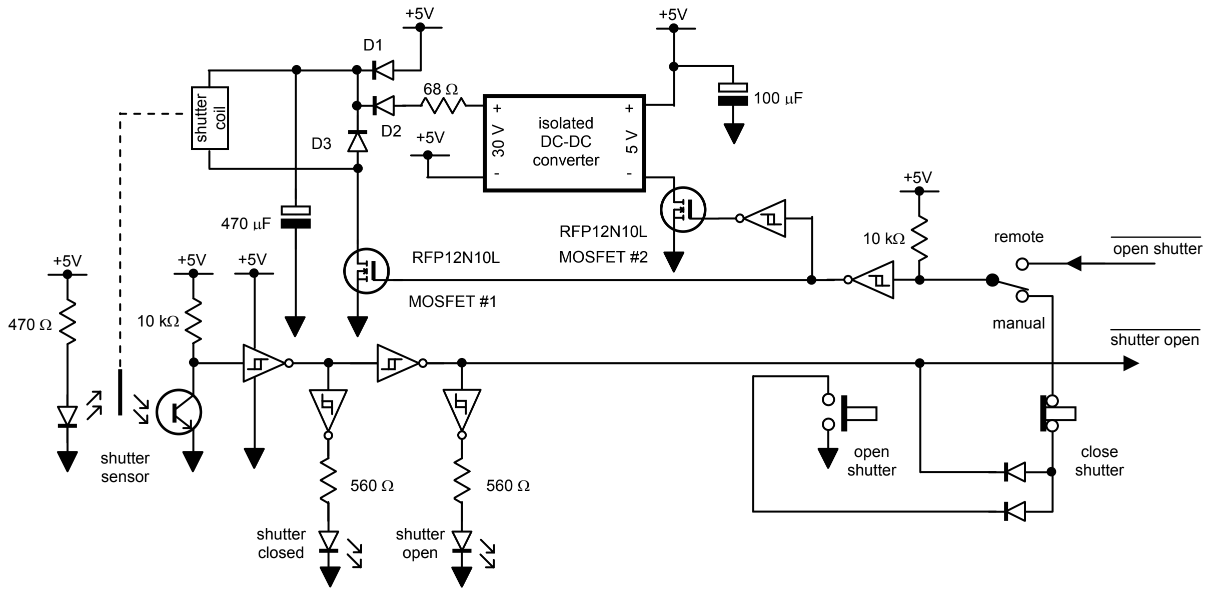
# Useful Circuits
## Gray Cancer Institute

1. Shutter driver circuit

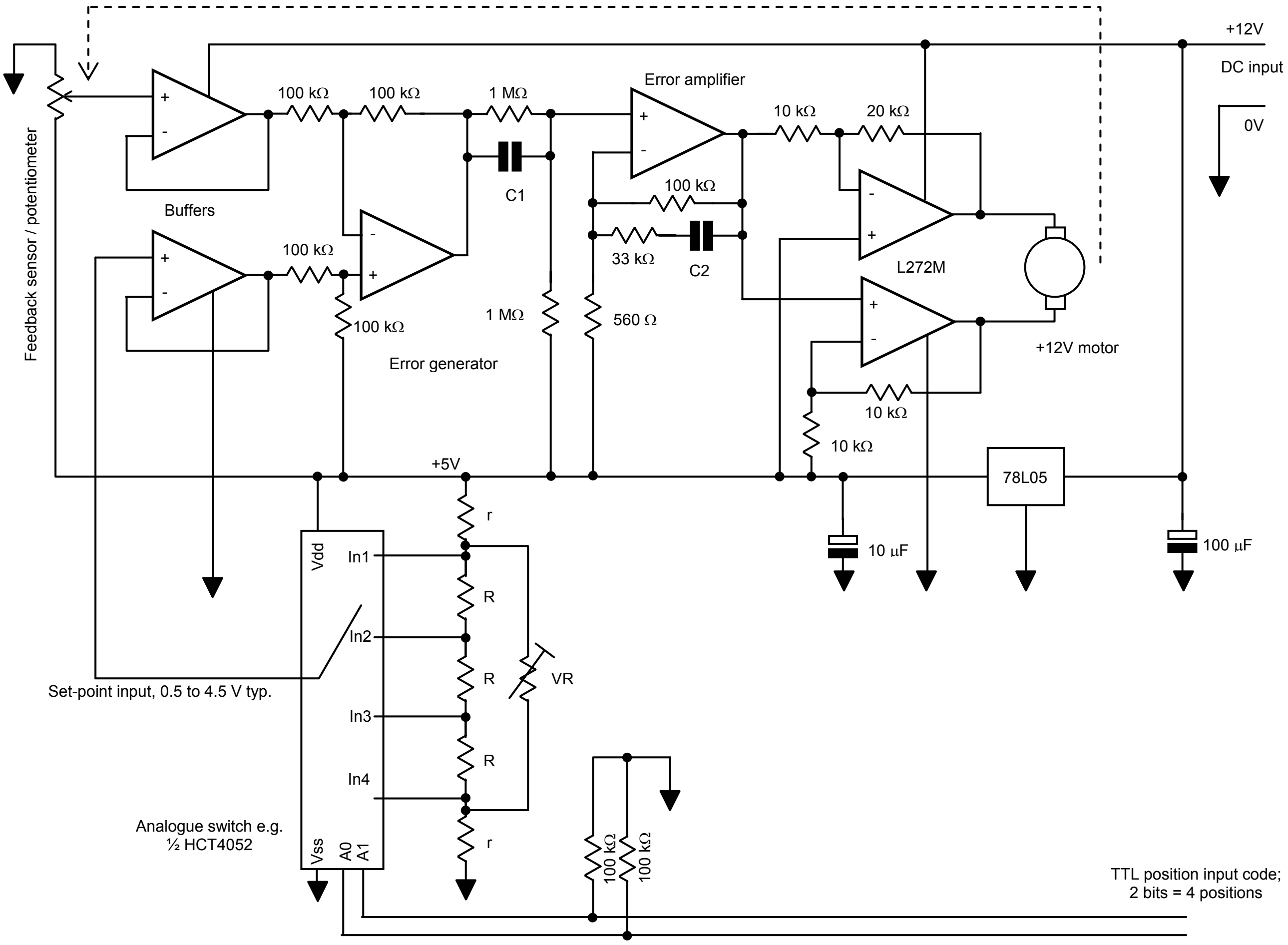



The DC-DC converter charges the 470 µF capacitor to around 35 V, through the 68 Ω current-limiting resistor and diode D2, since MOSFET #2 is normally 'on'. When an active low 'open shutter' command is received, MOSFET #1 is turned on, discharging the capacitor through the shutter coil and MOSFET #2 is turned off, preventing further charging of the capacitor. The shutter is maintained in the energised condition by the +5V supply and associated diode D1. The feedback sensor (opto-interrupter) senses the shutter state and indication is provided by two light-emitting diodes. The shutter can also be activated manually by pressing the 'open shutter' push-button. A latching circuit (two small-signal diodes) maintains the energised state until the normally closed 'close shutter' pushbutton is pressed.

The DC-DC converter is a 2-3 W unit and ensures that the 470 µF capacitor is recharged quickly (typically <<100 ms), ready for the next energisation cycle. Diode D3 is the usual back-emf snubber; its presence does delay turn-off to around 5 ms but ensures protection against high MOSFET drain voltages. All diodes are 1N 4007 series devices. If faster operation is required use a DC-DC converter with a higher output voltage and a correspondingly higher power rating. The hex-schmitt trigger inverters are within a 74HCT14 chip.

It is a good idea to keep the length of the cable to the shutter assembly as short as possible, particularly if the cores of a multicore cable are not individually screened: there is a possibility of capacitive coupling of the shutter drive pulse to the sensor input. It is a good idea to check the for this 'spike' with an oscilloscope and to place a small capacitor – 1-10 nF at the sensor input inverter to remove it.

2. Analogue servo circuit




A single +12V DC power supply is used in this position servo amplifier; a near mid-supply voltage, +5V, is derived from a 78L05 regulator and is also used as a reference voltage for both the set-point generator and the feedback sensor. The set-point is derived from a resistor chain (resistors R and r), switched by an analogue switch, in this example, 4 positions are set with a 2 bit code. Usually, the positions are 'equidistant' and resistors 'R' are thus of similar values, in the range 10-100 kΩ. The electrical rotation of the sensor potentiometer is usually around 340 degrees and the value of resistor 'r' is thus nominally less than R/2. A preset potentiometer, VR, can be used to set the span precisely, but the set-point should preferably be in the range of 0.5 V to 4.5 V or thereabouts. In practice up to 8 'positions' can be readily set up. There is no adjustment of offset; the sensor shaft is rotated within the drive mechanism to set this. The set-point and the sensor voltages are buffered before being applied to a differential amplifier which generates the error signal, centred on +5V. This error signal is amplified by an op-amp which also shapes the frequency response; the differential time constant is set by C1 and the integral time constant by C2, along with associated resistors. The values of these components are determined by the mechanical time constant/inertia of the system. The proportional gain is determined by the 560 Ω resistor, which should be made as low as possible without oscillation or overshoot.

The operational amplifiers need to be devices capable of single-supply operation; LT1013 dual devices or LT1014 quad opamps are very suitable. The motor is driven differentially by the bridge configuration L272 motor driver capable of supplying several hundred mA to the motor. Be sure to connect the motor the 'right' way round or feedback will clearly be positive rather than negative.

**Bi-directional drive indexing circuit**

There are instances when the positioning accuracy of a ‘proper’ servo position control circuit is not necessary, for example when a drive arrangement is needed to move between preset positions, such as in microscope objective turrets or when changing filters. In particular, where the mechanical position is indexed with some form of spring or detent mechanism, or when it is necessary to be able to remove the driven element completely, the circuit presented here is useful and reliable; it uses a handful of low cost logic chips.

The basic principle is to use some form of digital position sensor which senses the position rather rougly (here a 4 bit arangement is presented, i.e. 16 positions), in conjunction with a single, but more accurate logic sensor which defines the point at which the digital position sensor can be ‘read’. This point is defined by the detent mechanism or by the precision of the index on the driven element. For example, the position sensor code can consist of ‘holes’ in the driven element, sensed by a transmissive LED/phototransistor photo-interrupter. An alternative, as shown in Figure 1, is to use reflective marks in conjunction with a reflective opto-sensor. Hall effect switches and magnets are another possibility. The basic circuit is shown in Figure 2. A double buffered latching arrangement stores the ‘current’ position and passes this to a comparator (CD 4585 B) which eventually drives the motor in the appropriate direction. Any change in the ‘set position’ code causes the comparator to re-enable the sensors and to drive the motor away from the current stored position. The sensors are disabled once the correct position has been reached to prevent stray IR light (when photo-interrupters are used) from reaching any light-sensitive detectors used in the rest of the system. The 5$^{th}$ (mark) bit is used to latch the 4-bit input code into the 74 HCT 175 quad latch. A second, transparent, latch (CD 4042 B) transfers the ‘actual’ position code to the CD 4585 B 4-bit comparator; the ‘<’ and ‘>’ outputs are used to determine the direction of the drive motor. When a match between the ‘set position’ and the ‘reached position’ code is found, the ‘=’ output from the comparator latches the current state into the CD4042B and disables the sensors.

If the complete driven assembly needs to removed (e.g. when a gear-driven slider or outside edge-driven gearwheel is used), one of the sensed positions needs to be sacrificed. The fact that the driven element has been removed is indicated (in the example below) by the presence of ‘0000’. If a removable driven element is used, code 15 is invalid, i.e. it signifies that the driven element has been removed; this is detected with a 4 input NOR gate implemented with 4 diodes. This need not be implemented when removal is not necessary.

Clearly the exact details of the mechanics determine the type of sensor and motor used. Miniature reflective sensors such as the Kodenshi SG2BC allow close mark spacings to be used. For most lightweight drive systems, small DC motors consuming no more than a 1-2 watts are perfectly adequate and easily driven by a ‘H bridge’ type of driver, readily implemented with a chip intended for driving power-MOSFET gates, such as the TC4426. The motor can be enabled or disabled through 2 input NAND gates which precede the motor driver.

Figure 1: A version of a linear gear-driven element designed to hold 4 filters. Each element contains a set of 4 holes that are ‘filled’, where appropriate, with a reflective pin to generate position code with reflective sensors.

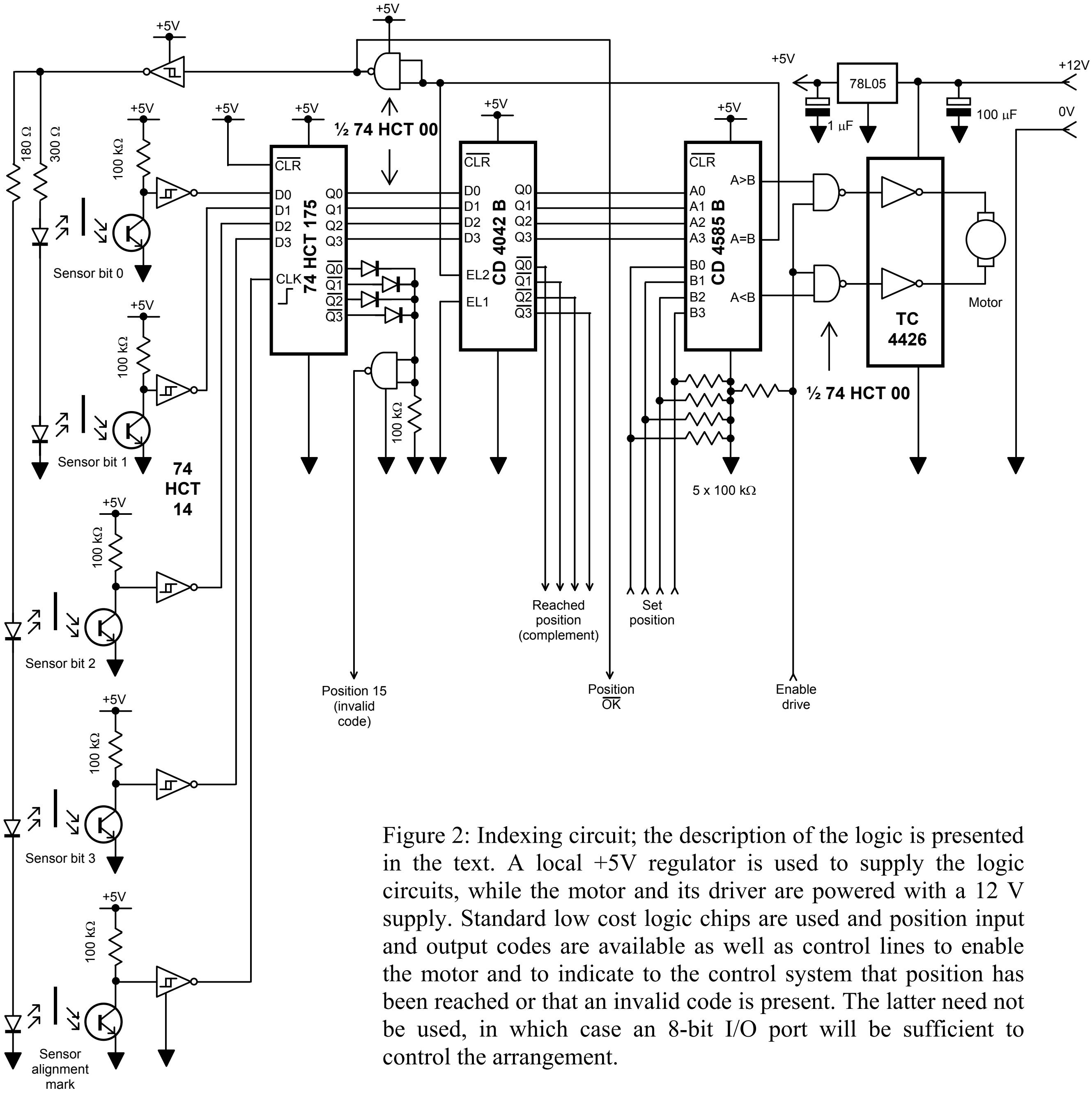



Figure 2: Indexing circuit; the description of the logic is presented in the text. A local +5V regulator is used to supply the logic circuits, while the motor and its driver are powered with a 12 V supply. Standard low cost logic chips are used and position input and output codes are available as well as control lines to enable the motor and to indicate to the control system that position has been reached or that an invalid code is present. The latter need not be used, in which case an 8-bit I/O port will be sufficient to control the arrangement.