FEATURE

Build a Universal Controller For Small DC Motors:

An Introduction In Designing Intelligent Machines

by Donald Wilcher

Out on the market, there are a series of electronic control robots known as MOVIT® available to hobbyists and experimenters. These toy robots employ sound or infrared sensors to detect objects in their path and upon detecting these objects will change their direction. Some of the MOVITs have on board computers, making them programmable. With the use of sensors and a microprocessor to interpret the data picked up from the sensors, these machines are capable of making decisions (e.g. to avoid an object or to track a pencil marked line) about their environment. The focus of this project is to introduce to the reader how such machines are capable of motion based on the data obtained from their sensor(s) and how this information is delivered to the machine's motor drive mechanism. Besides discussing methods of motor control, a Universal Controller for small dc motors (in the range of 1.5 - 12 VDC) will be introduced along with a design example of an intelligent machine.

DC Motor Control Basics:

The ability to start or stop a motor is basically no more than adding a switch to the circuit. Fig. 1 illustrates a simple start/stop circuit for controlling a dc motor. The basic operation of this circuit is, with the switch open, dc current is unable to flow through the motor windings. With no I_a (armature or motor winding current) present, the motor doesn't rotate. If the switch is closed, I_a flows through the motor windings allowing the rotor to rotate from the stator thus producing motion in the shaft of the motor. This circuit is adequate if one direction of rotation is required but will not suffice for bidirectional motion. Fig. 2 illustrates how bidirectional control of a motor can be accomplished. Simply, by closing SW1 and leaving SW2 open, I_a flows and the motor's shaft rotates in one direction. If SW2 is closed and SW1 is open, we now have a $-I_a$ and the motor rotates in the opposite direction. Closing SW1 and SW2 together is not permitted because the power supply source for the circuit will be shorted out (i.e. +5-5 = 0V). This design scheme is better than the first one but its main drawback is its manual mode of operation. A human interface of some sort must be utilized in manually opening and closing switches 1 or 2. The solution to this problem is to use electromechanical relays. Simply explained, with the coil of the relay ener-

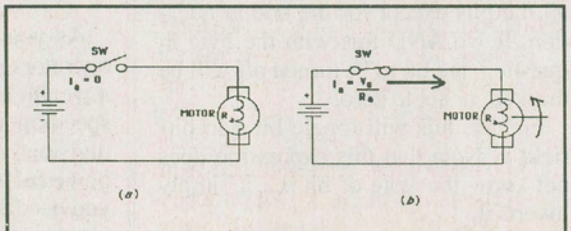

FIGURE 1
Start/Stop Control For A DC Motor
(a) Switch Open: No I_a, motor is stopped
(b) Switch Closed: I_a flows, motor rotates

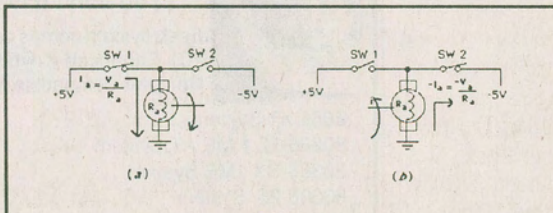

FIGURE 2
Bidirectional Control For A DC Motor Using 2 Switches
(a) Motor Rotates In Forward Direction
(b) Motor Rotates In Reverse Direction

gized the contacts switch from normally open to closed contacts automatically. This feature of automatic switching ties into the design concept of intelligent machines. The main objective of an intelligent machine is to allow the system to make a decisive response based on the information it has obtained

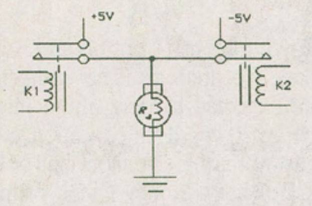

FIGURE 3
Bidirectional Control For A DC Motor Using Two Electromechanical Relays

from the environment. Fig. 3 shows a bidirectional control circuit using electro-mechanical relays.

Universal Controller Components

Now that we have a basic understanding of how a dc motor can be controlled in terms of motor shaft direction (forward/reverse), we have the knowledge to build a motor drive circuit which can be applied to any device or machine that needs to change direction or motion. A Universal Controller is basically a modified circuit of what was

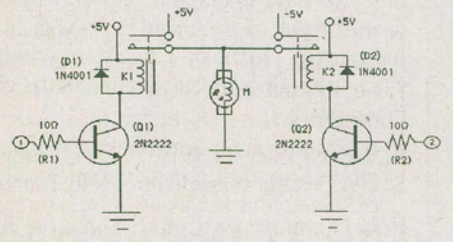

FIGURE 4
A Universal Controller For DC Motors

discussed in Fig. 3. Fig. 4 shows the basic circuit of the Universal Controller for dc motors. The circuit in Fig. 4 operates as follows: With no input voltage applied at pt. 1, VB1 is 0V. Collector to Emitter Current (ICE) is also 0, therefore, K1 is not energized; the motor (M1) will be in a non-rotating state. Upon voltage being applied at pt.1 (VIN .7V) ICE is generated thereby energizing K1. The contacts of K1 will switch from N.O. (normally open) to closed contacts allowing I_a to flow. With I_a flowing, the motor's rotor rotates and motion is thereby induced. If an input voltage is applied at pt. 2, circuit operation is the same except the motor's shaft will rotate in the opposite direction. Diodes D1 and D2 are used to suppress inductive spikes generated by the energization/de-energization of the relay coils. If input voltages are applied to pts 1 and 2 simultaneously, relay contacts K1 and K2 will short out the power supply. Therefore, applying voltages at both Q1 and Q2 BASES are not allowed. If higher rated motors are required, the contacts for K1 and K2 should be rated accordingly to handle this voltage value. As mentioned previously, this circuit can be applied to any device or machine that requires motion.

Introduction To Intelligent Machine Design

An intelligent machine is a device or system capable of making decisive responses based on the data obtain from the environment. The decision-making response is based upon a software/μP (microprocessor) elements system which obtains data from its sensor(s) and processes this information to produce the corresponding output. Some machines may have the ability to make decisions based on the data obtained from the environment but may not possess the software/μP elements. The reason for these machines being able to make decisive responses is due to the circuit configuration and logic incorporated into the system. The following example will give a hands-on approach in designing and developing an intelligent machine using the Universal Controller as the main motor drive mechanism and without the use of software/μP elements.

A Toy Robot Walker

The objective of this project is to develop a motorized walker that upon detecting light will initiate motion either in the forward or reverse direction. In this project, the ROBOTIX® Construction Set made by Milton Bradley will be used in constructing this

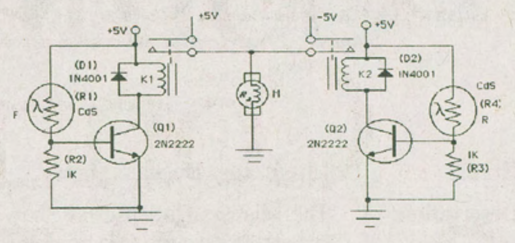

FIGURE 5
Light Detection Circuit For Toy Robot Walker

machine. Although the ROBOTIX Construction Set was used, the techniques presented here can be applied to other motorized construction sets as well. The ROBOTIX Construction Set consists of 4 motors, a remote control console and an assortment of plastic couplings, beams and wheels. With the number of parts available, a 4-axis robot can be constructed and, with the use of a personal computer and software, the machine can be programmed to perform manipulative tasks. The Light Detection Circuit for the walker is shown in Fig. 5. The circuit operates in the same manner that was described under the Universal Controller Components Section. The CdS (Cadmium Sulphide) or photocells along with the 1K resistors form voltage dividers which provide input voltages to the bases of the NPN transistors Q1 and Q2. With light present on R1, the walker moves forward and with light on R4 the machine moves backward. As discussed earlier, the photocell sensors pick up the data (i.e. light) and send this information to the Universal Controller. The Controller then makes the decision either to move forward or backwards based on this data; therefore a simple intelligent machine has been created.

Construction Notes

The circuit in Fig. 5 was built on a solderless breadboard and circuit operation validated. The photocells were separated "x" inches apart so that the beam of light would not energize both K1 and K2 relays at the same time. For best results, cardboard tubing placed over both photocells will im-

see **Controller**, *page 38*

Controller, *Cont'd. from page 27*

prove circuit operation. Fig. 6 illustrates how the Remote Control Console was modified for circuit interfacing.

Further Reading and Experimentation:

It is hoped that the reader now has a better understanding of how MOVITs and other intelligent machines function and with this knowledge, he/she can design his or her own machines or systems. There are several good books out on the market that explain how to construct robots or intelligent machines two of which are given here: *Microprocessor Based Robotics* by Mark J. Robillard and *Android Design* by Martin Bradley Weinstein. These two books start from the basics of intelligent machine design and work their way through complex systems design and construction of smart machines. These two books can be found in any good technical library. Heath/Zenith Electronics Self Study Course Microprocessor Applications, Model EE-3405 has several chapters on dc motor control as well as hands-on experiments for practical learning. Contact your local Heath/Zenith Electronic Store for further information on this course and other self-study courses. As for further experimentation with this subject, try to design machines that are capable of detecting and responding to metallic objects or temperature differences. If you have junk box parts available, see if you can design a system where coming in contact with a metallic object, the machine will change direction and turn on an audible or visual alarm. GOOD LUCK ! ! ! ❐