RePlay Switch Controller
January 13, 2011

Introduction

There are several types of toys that are difficult to adapt for use with a single pushbutton switch. Toys that have reversible motors most often have a mechanical double-pole, double throw type switch with a center off position. With toys that have multiple functions, the volunteer has to decide which function to adapt. Toys that have an electronic controller chip often have carbon pill type pushbuttons that are susceptible to electrostatic discharge. It is almost impossible to solder a wire to the tiny foil area under the carbon pill.

So, the idea is the "RePlay Switch Controller" which uses a low-power microcontroller. The user's pushbutton generates an interrupt event that wakes up the device in a low-power mode, services the request and shuts down on return from the interrupt program. The low power mode maintains the RAM memory to for the next pushbutton event. There are several modes of operation that are configured with a PC app when installed in a particular toy.

Types of Toys

1) One metallic switch contact:

Toys that have a single switch without electronics will continue to be adapted as usual. An exception might be with devices with a toggle switch. In these cases, the switch controller can be configured in on-off mode to replace the toggle switch so that the push button doesn't have to be held down to keep the device on.

2) Motorized toys with metallic DPDT, center-off switch:

Toys that are motorized with metallic DPDT, center-off switches will require both N-channel and P-channel FETs to control the motor current. The metallic switch needs to be disabled to insure that the switch doesn't create a short circuit condition when the FET's are on. Each motor requires two outputs to drive the motor clockwise and counter-clockwise. The remaining outputs can be used for light and sound functions. The motor outputs are configured as retriggerable one-shots to keep the motor running while the push button continues to be pressed. In some cases, the motor outputs might be configured in on-off mode so that the first push turns the motor on and the second push turns it off. The motor circuit is shown in **Figure 1.**

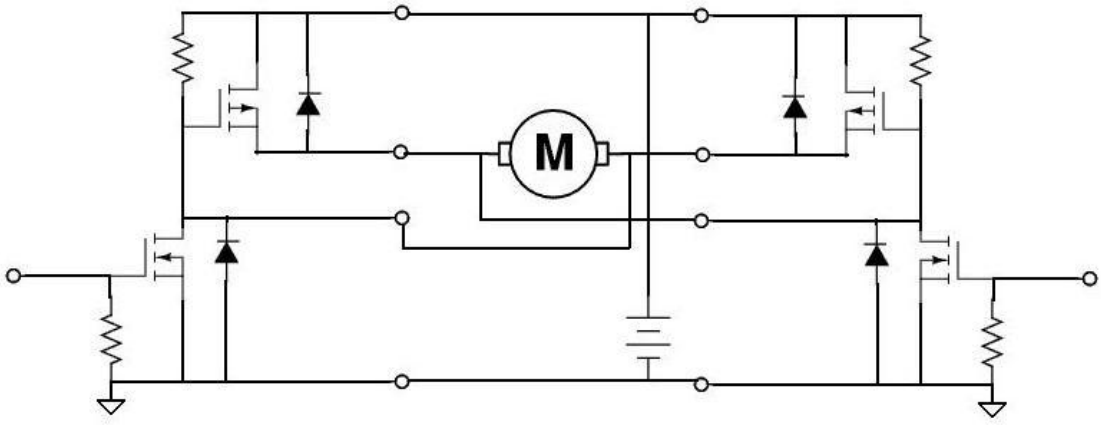

Figure 1. Two Switch Controller outputs replace a DPDT, center-off metallic switch.

Note: Some motorized toys have the switches remote from but wired to the toy. If the batteries are in the toy, the entire remote can be eliminated. Unfortunately, if the batteries are in the remote then the remote needs to be adapted.

3) Remote controlled toys:

Although toys with wireless remotes look like some DPDT switch used on wired remote toys, the switches are single contact and are adapted as toys with push buttons. (I think this is true but need to verify.)

4) One switch with electronics:

Toys with a single switch and electronics (similar to the circuit shown in **Figure 2**) should be adapted with a simple circuit to protect the sensitive electronics from Electro-Static Discharge (ESD). Also, smaller gauge wire would help will soldering to the small traces usually found with comb switch pads and Chip-On-Board (COB) circuits.

5) Multiple carbon pill switches with electronics:

Toys with multiple switches and electronics (see **Figure 4**) are ideal for the switch controller. Configuration options allow for the switches to be pressed in any sequence. The version of the switch controller and the method of wiring depend on the toy. See the next section, Other Considerations, for details.

6) Keyboard matrix:

Toys that have a large number (> 8) of switches, e.g. keyboards, usually have the switches wired in an X-Y matrix configuration. The current design of the switch controller is not capable of adapting this type of circuit.

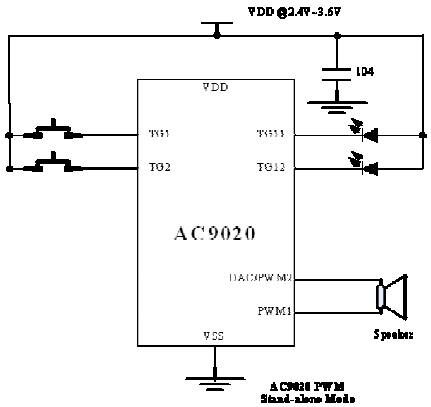

Figure 2. The AC9020 is a 20 Sec. PWM or DAC voice output with high quality speech. Up to 2 input pins and 2 I/O pin control simple sound/speech for 20 Sec. Voice Length at 6 KHz sampling and 4 bit hardware compression. Maximum 64 voice groups.

Other Considerations

1) Power Source Voltage:

The microcontroller operates on the voltage range supplied by 2 alkaline batteries (3.1 vdc (new) to 1.8 vdc (end of life)) or one lithium coin cell (3 vdc nominal). Since the toy's circuitry is at the same voltage as the microcontroller the outputs can be connected directly to the toy's inputs (logic inputs, not motors. See Current Requirements.

If the toy is powered by different batteries, e.g., 3 or 4 alkaline batteries or a 9 volt battery, then an LDO needs to drop the battery voltage to the microcontroller. Since the toy is operating at a higher voltage than the microcontrollers, the N-channel or the P-channel FETs are needed for level shifting. See High Side or Low Side.

2) High Side or Low Side

Potentially the hardest part of using the switch controller is determining the common side of the switches. Some circuits have the switch connect the toy's input to the positive or + side of the battery (High Side) and the remaining circuits have the switch connect the toy's input to the negative or GND side of the battery. If the circuit uses high side switches then the switch contact is wired to a P-channel FET; low side circuits use the N-channel FETs.

3) Current Requirements

Even if switch controller is powered directly from the toys batteries, the FETs are still required if the switch controller is directly powering a light, buzzer, motor or any other higher current electrical device. The outputs of the microcontroller can directly drive an LED or a logic input but the FETs are required for any other higher current loads.

Configuration Options

Switch Type:

The user's switch is usually a momentary contact but can be a toggle switch. In either case, the logic is edge-triggered, that is, Normally Open (N.O.) - triggered when the contact closes. The current design of the switch controller does not support Normally Closed switches.

Modes of Operation:

1) One-shot: Every push turns on the next output in sequence for a short pulse (~100 milliseconds). The one-shot masks the switch bounce and the microcontroller goes into sleep mode after the short pulse. The switch has to be released before the next push can be detected (generate an interrupt).

2) Retriggerable one-shot: Every push turns on the next input in sequence. As long as the push button is held on, the one-shot retriggers which keeps the output on. The one-shot masks the switch bounce and the microcontroller goes into sleep mode when the one-shot times out. In order to save the batteries, after a maximum on time (~1 minute), the µC turns the output off and goes to sleep. The switch has to be released before the next push can be detected (generate an interrupt).

3) On-off: The push turns on the next output in sequence and keeps it on until the switch is released and pushed again. A one-shot masks the switch bounce. The µC goes into sleep mode during the off period. In order to save the batteries, after 1 minute, the µC turns the output off and goes to sleep. The switch has to be released before the next push can be detected (generate an interrupt).

Number of Outputs:

The number of output used is configured, from one output to the maximum number of outputs (1 to 8).

Sequence of the Outputs:

Since some toys use a particular sequence of button pushes to generate different functions, an array of outputs is configured to program the sequence of the outputs in the rotation. For example, with the Fisher Price Roll-Along Turtle the sequence of the buttons changed the functions. It is fun and the pushbutton sequences though all of the words – One, Two, Three, Four, Triangle, Square, Circle, Heart and the song. Pushing the top button plays the song and resets the other four buttons to start with numbers. The turtle was configured wit a sequence of 1,2,3,4,1,2,3,4,5.

“Fixed” Configuration Constants:

Some configuration constants are unlikely to change and will only be configured from an advanced menu.

1) One Shot Pulse Width - The one shot pulse width can be configured in increments of ~100 milliseconds.

2) Maximum On Time - To save the batteries, the maximum time an output can remain on can be configured in increments of ~100 milliseconds.

3) Resistor Pull-up Time - The time the resistor is pulled up before the closed switch state can be tested. Time in ~.1 milliseconds.

4) Switch Test Time - The switch test time plus the resistor pull-up time is the time between tests of a closed switch in increments of ~100 milliseconds.

Prototype

The first toy adapted with the switch controller has multiple carbon pill switches with electronics. The toy is the Roll-Along Turtle in the Fisher Price Laugh and Learn series (**Figure 3**). There are more than 12 different toys in this series with the same electronics. It is powered by 3 AAA alkaline batteries and uses low side switches. This toy requires the version of switch controller with the LDO and the FET's. See Other Considerations.

Figure 3. Roll-Along Turtle with 5 push buttons, a speaker and light.

The circuit provides for reverse-current protection (Q1), an LDO to reduce the battery voltage (4.5 vdc) to the microcontroller supply voltage (3.3 vdc) and 5 N-channel FET's to drive the toy's switch contacts. (The unused FET's were not populated on the prototype.)

The toy was configured as One-shot, 5 outputs with a sequence of 1,2,3,4,1,2,3,4,5 as described as an example above. The adapted toy is shown in **Figure 4.**

Figure 4. The first switch controller prototype was used to adapt a Fisher Price Roll-Along Turtle.

Examples of Toys

1) One metallic switch contact:

2) Motorized toys with metallic DPDT, center-off switch:

3) Remote controlled toys:

4) One switch with electronics:

5) Multiple carbon pill switches with electronics:

6) Keyboard matrix: