Application Note

Smart Z-Toy Wireless Remote

AN010104-0608

Overview

Infrared (IR) remote control is becoming common in the average household. Hand held remotes are used to control televisions, VCR's, cable boxes, satellites, DVD's, receivers, and so forth. IR remote control is a low cost implementation for wireless control in everyday life. IR remote control does not require an antenna or coil as it is radio frequency control, nor it must be FCC compliant because it does not interfere with electrical appliances or communication equipment. IR remote control requires a simple IR LED and an IR demodulator. IR remote control is widely used, however, not in popular electronic toys.

> **Note:** *The source code file associated with this Application Note is AN0101-SC01.zip, and is available for download at www.zilog.com.*

One real-life application is to control the children's toys by muting the sound from the toy at the same time the television is muted. This is useful when there is an incoming phone call or an important conversation.

This application note outlines how to generate a music tone and decode an IR signal so it can be easily implemented in toys or other wireless control applications using one of Zilog's high performance microcontrollers unit (MCU). The Z8® MCU has two independent timers that are ideal for generating frequencies and periods with very little firmware overhead.

Discussion

Tone Generation

A melody is a combination of frequencies and periods. The Z8 MCU has two timers: T0 and T1. In this application, T0 generates a frequency and T1 counts the period for each tone. For example, middle C has a frequency of 262 Hz. T0 must toggle the output pin at 524 times/second (262 x 2).

Microcontroller does not generate a pure sine wave. It generates a rectangular waveform that has the fundamental frequency plus other higher harmonics. These harmonics produce a melody with a slightly higher tone. Piezo buzzers have better output at higher frequencies, therefore, higher harmonics produce a better sound.

Musical toys or music boxes always use a higher tone and faster rhythm to make the music lively. The eighth higher tone is arbitrarily chosen for this application note (H = 8). Table 1 defines the terms used in the equation for the relationship between the tone frequency and the timer.

Table 1. Definition of Terms for Tone Frequency Calculation

Crystal Frequency:	XF	8 MHz selected
Pre-scaler:	P	to be loaded to PRE0 register
Initial Value:	I	to be loaded to T0 register
Tone Frequency:	T	from musical note
Higher tone:	H	H = 8 is chosen

To generate tones from the timer, the following equation is used:

$$2 \times T \times H = XF/(2 \times 4 \times I \times P)$$

$$I = XF/(16 \times T \times H \times P)$$

$$I = (XF)/(256 \times T) \text{ with } H = 8, P = 2$$

$$I = 31250/T$$

For detailed description of the timer, refer to *Z8 CPU User Manual (UM0016)*.

To generate the tone frequency, an output toggles at the rate of two times the tone frequency. A general-purpose register is used to store the logic of that output. When the T0 timer expires, that register is toggled and then loaded to the output pin. In the 40-pin Z8 microcontrollers or IR remote controllers, it is done automatically in every timer interrupt.

Table 2 lists the tone frequency and corresponding initial values for the Z8 MCU.

Table 2. Tone Frequencies and Corresponding Initial Values

Crystal frequency:	**XF**	**8000000**		
Prescaler:	P	2		
Higher Tone:	H	8		
Initial Value:	I			
				PH = 16
Music Tone			Tone Frequency (T)	Initial Value (I)
Lo	C	do	131	239
Lo	C#	#do	139	226
Lo	D	ra	147	213
Lo	D#	#ra	156	201
Lo	E	me	165	189
Lo	F	fa	175	179
Lo	F#	#fa	185	169
Lo	G	so	196	159
Lo	F#	#so	208	151

Table 2. Tone Frequencies and Corresponding Initial Values (Continued)

Crystal frequency:	**XF**	**8000000**		
Lo	A	la	220	142
Lo	A#	#la	233	134
Lo	B	ti	247	127
Middle	C	do	262	119
Middle	C#	#do	277	113
Middle	D	ra	294	106
Middle	D#	#ra	311	100
Middle	E	me	330	95
Middle	F	fa	349	90
Middle	F#	#fa	370	84
Middle	G	so	392	80
Middle	F#	#so	415	75
Middle	A	la	440	71
Middle	A#	#la	466	67
Middle	B	ti	494	63
Hi	C	do	523	60
Hi	C#	#do	554	56
Hi	D	ra	588	53
Hi	2	#ra	622	50
Hi	E	me	660	47
Hi	F	fa	698	45
Hi	F#	#fa	740	42
Hi	G	so	784	40
Hi	F#	#so	830	38
Hi	A	la	880	36
Hi	A#	#la	932	34
Hi	B	ti	988	32
HiHi	C	do	1046	30
Quiet				**255**
Endmark				**254**

Period Generation

The period for the tone is counted by the T1 timer. T1 is configured to generate an interrupt according to the following formula:

$$\text{T1 interrupt frequency} = XF/(2 \times 4 \times P \times I)$$

$$= 8000000/(8 \times 2 \times 200)$$

$$= 2500 \text{ Hz}$$

$$\text{T1 interrupt period} = 400\mu s$$

When the T1 interrupt occurs, register ‘timer 100 ms’ is used to count for 100 ms (400 µs x 250 = 100 ms). This period is used as a basic unit for the tone period. There is a ‘factor’ to scale up the period to the required timing resulting in a different combination of tones and periods.

The melody is stored in the source code look-up table under song1 and song2. Bytes are paired so that the first byte defines the frequency and the second byte defines the period. The program finds the starting address of each song and continues loading the melody until the ‘endmark’. The ‘endmark’ is always the hexadecimal symbol for number 254. The hexadecimal symbol for number 255 is used if the melody is a quiet period.

Infrared Signal Format

IR signals are a series of ‘ON’ and ‘OFF’ transmissions of the IR LED. Most common IR signals use a constant carrier frequency. During the ‘ON’ time, or Mark, the IR LED transmits the carrier frequency to the IR receiver. In the ‘OFF’ time, or Space, is the time when no signal is being transmitted.

An IR demodulator (Sharp GP 1U5) is used to filter the carrier and provide a pure Mark Space signal. This type of demodulator is widely used in television and VCR industries to receive IR signals. The demodulated signals for an RCA television’s Volume Up, Volume Down, and Mute buttons are displayed in Figure 1.

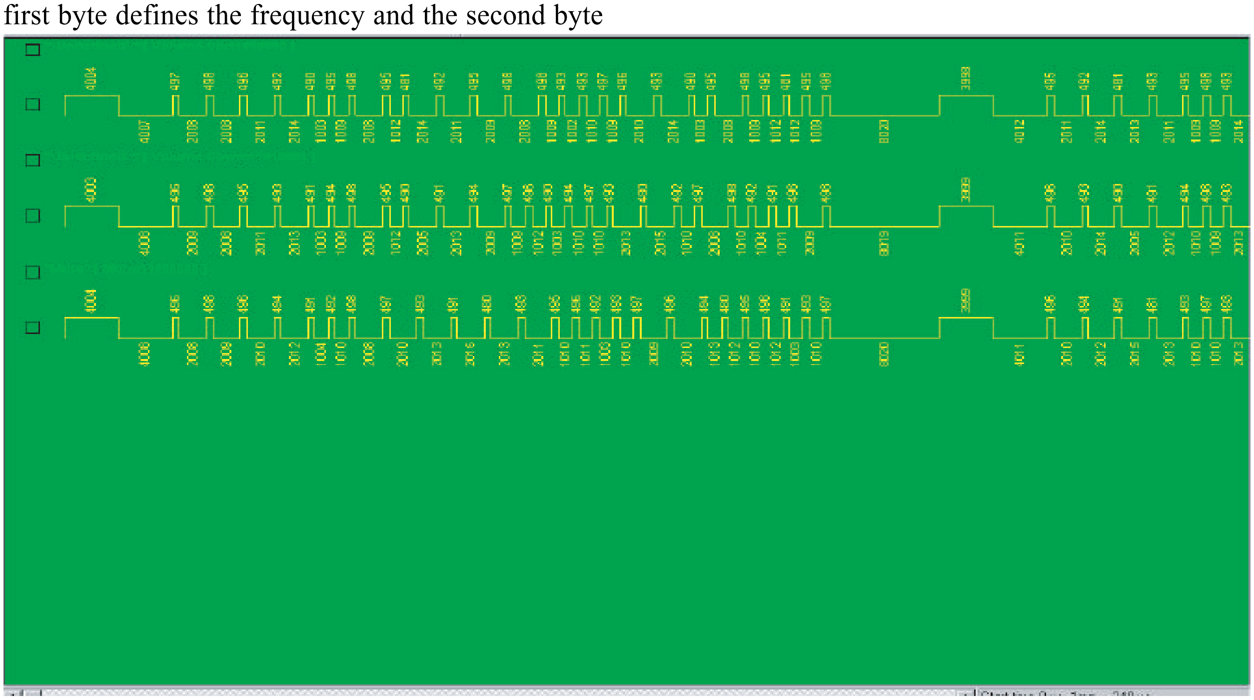

Figure 1. Sample Remote Control Signals from an RCA Television

Infrared Signal Decoding

IR signals are made up of a combination of Mark and Space symbols. The Z8 MCU reads the Mark and Space timing to decode IR signals. P31 is used as the input for the IR signal. The demodulated signal is normally high and is connected to P31. The P31 interrupt is generated when a falling edge is detected at P31. The controller determines if the signal matches the specification, by counting the period between two falling edges.

T1 generates a 200 µs timing interval. The register **pulse_length** is used to count the length of each pulse. Each count represents 400 µs.

The header 4000 µs + 4000 µs = 8000 µs which is equal to 20 counts.

Data0 is 500 µs + 2000 µs = 2500 µs which is equal to 6.125 counts.

Data1 is 500 µs + 1000 µs = 1500 µs which is equal to 3.750 counts.

The long break is 500 µs + 8000 µs = 8500 µs which is equal to 21.125 counts.

The header is first detected and compared with the range 15 to 25. Then the data is accepted only in the range 2 to 8. It is recognized as Data1 if it is less than 5, and as Data0 if it is higher than 5. The header and 24-bits are read. The data bit and its complement are then extracted. These data are examined to see if they match the Volume control command.

By combining the P31 interrupt and the T1 timer, the IR signal is detected easily by the Z8 MCU.

Volume Control

Each bit in Port 2 can be configured as either input or output. The volume is increased or decreased by configuring different numbers for port 2 to drive the Piezo buzzer. P2M is the register that controls port 2 as input or output. The input pin has a high impedance and the output pin drives extra current to increase the buzzer volume. Resistors can be modified to different volume levels.

In this application, P20, P21, P22, and P23 are used to demonstrate the volume control application. You can use different numbers of ports or different driving circuits or pulse width modulation to control the volume.

Results of Operation

The Smart Z-Toy can play the melody of the 'Malaysian National Anthem' and 'Happy Birthday' by pressing switches 1 and 2 respectively. With an RCA remote control, the volume can be increased, decreased, or muted. Different melodies can be input by adding the frequency and period, then ended with the 'endmark'.

Zilog's Z8 MCU can generate melodies and decode IR signals easily with less than 500 bytes of memory.

Test Procedure

Equipment Used

RCA remote control.

General Test Setup and Execution

Follow the step below to setup and execute the test:

1. Press switch 1 or 2. The selected melody plays.
2. Point the RCA remote control to the IR receiver.
3. Pressing Volume Down button of the RCA remote decreases the volume level.
4. Pressing Volume Up button of the RCA remote increases the volume level.
5. Pressing Mute button of the RCA remote mutes the melody.

Test Results

The melody is played and the volume is controlled by the RCA remote control.

Appendix A—Schematics

Figure 2 displays the schematics of Smart Z-Toy.

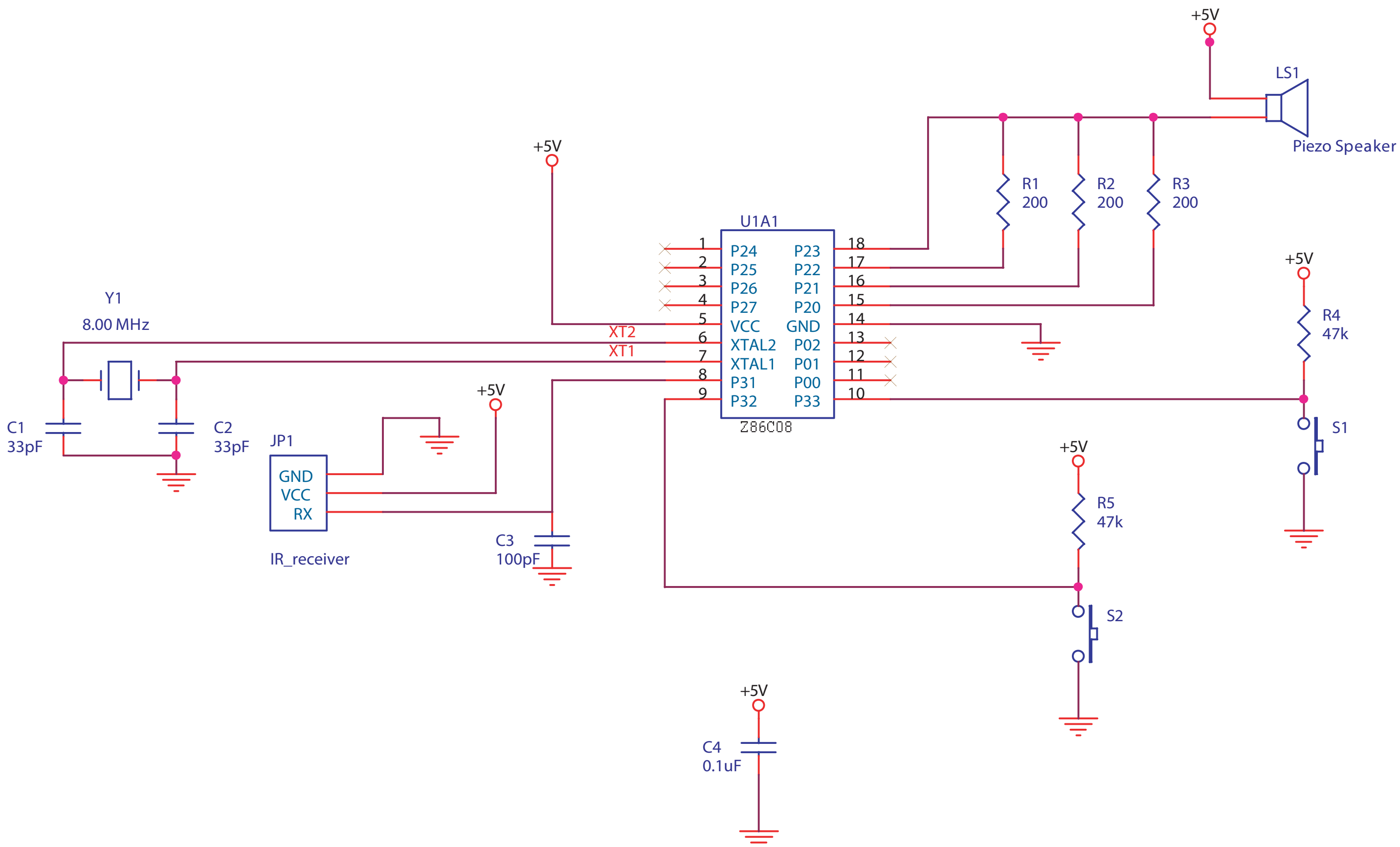

Figure 2. Schematics of Smart Z-Toy

Appendix B—Flowcharts

This Appendix displays the flowcharts of Main Program, Timer1 400 µs interrupt, and P31 IRQ2 interrupt. Figure 3 displays the flowchart for the Main Program.

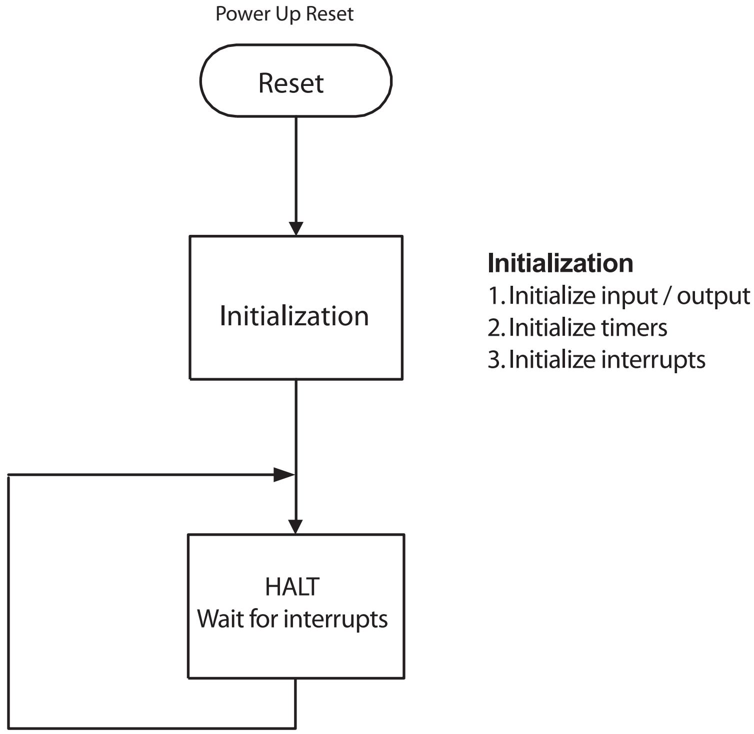

Figure 3. Flowchart for the Smart Z-Toy Main Program

Figure 4 displays the flowcharts for the Timer1 400 µs interrupt.

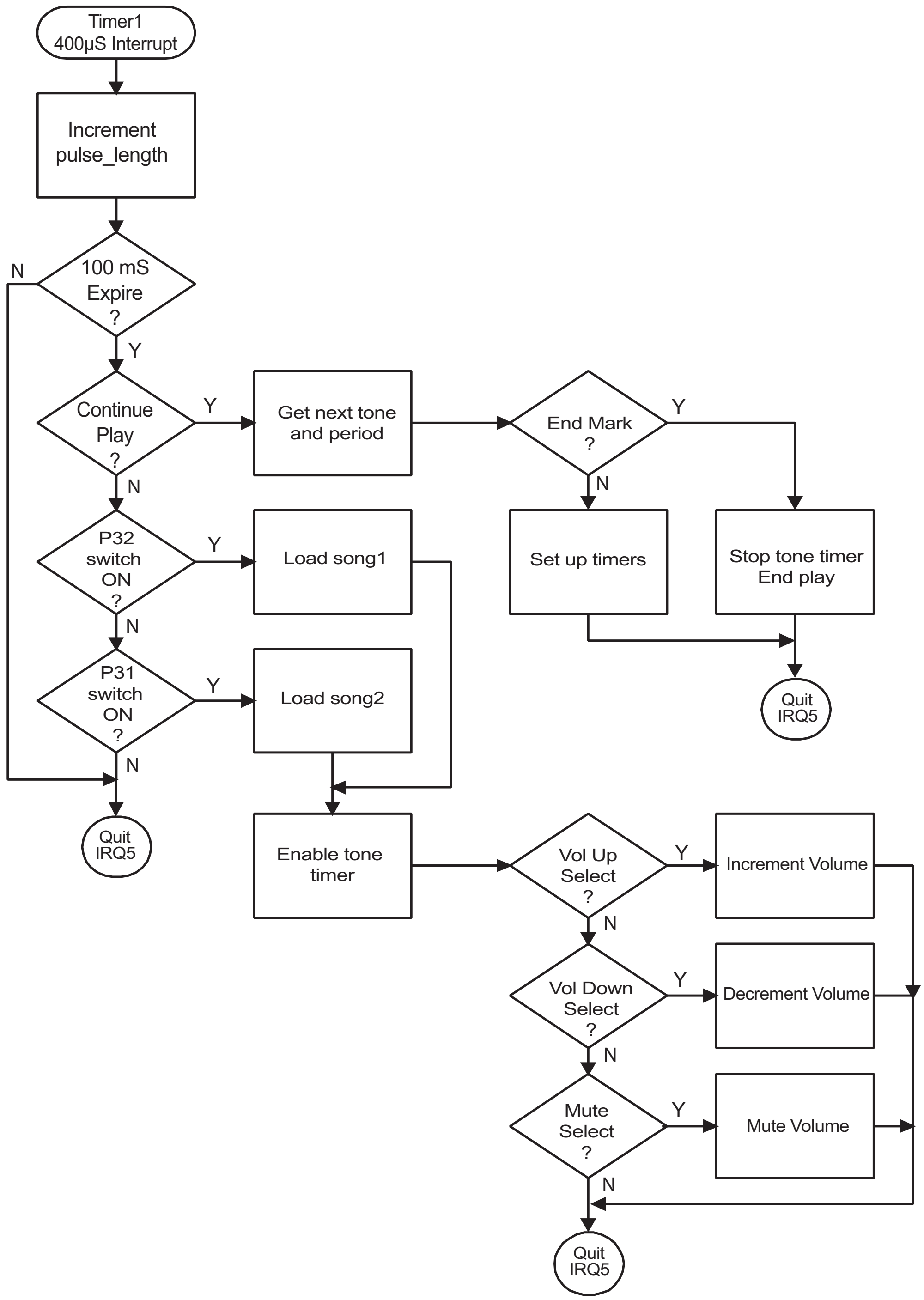

Figure 4. Flowchart for Timer1 400 µs Interrupt

Figure 5 displays the flowchart for the P31 IRQ2 interrupt.

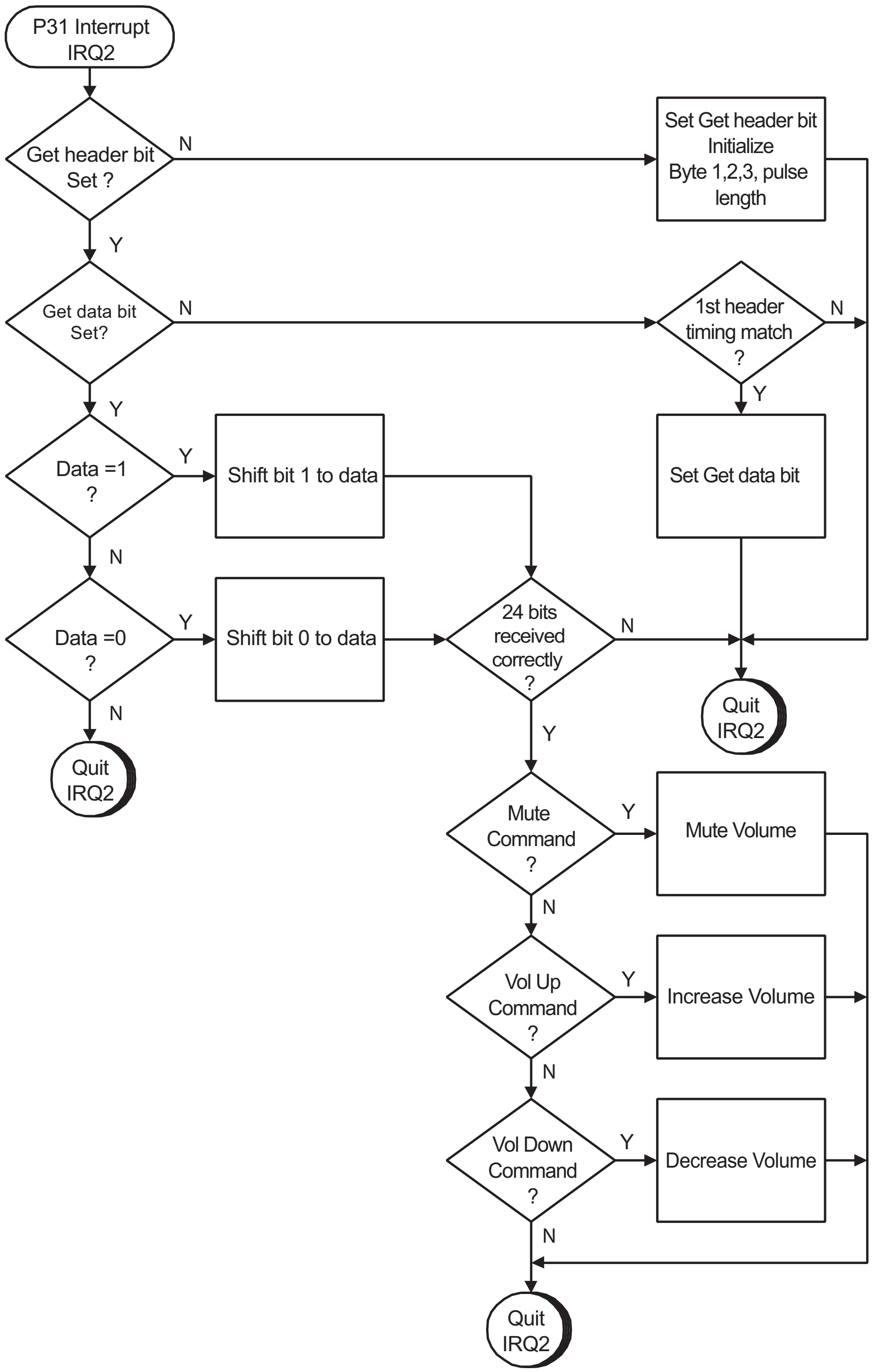

Figure 5. Flowchart for P31 IRQ2 Interrupt

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