Pulse Generator Controlled by Microcontroller

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Abstract. *Pulse generator with parameters controlled by microcontroller is described. All the timing circuits are included in a microcontroller, which is used to control the operation of the instrument. The amplitude of the output pulses is controlled using an adjustable power supply source of the generator output stage. Software is also briefly described.*

Keywords

pulse generator, pulse amplitude control, microcontroller.

1. Introduction

Pulse generators are often used in troubleshooting, development and many other applications where it is necessary to use pulse-shaped test signal. First of all, such pulse generator is used to provide known test conditions for the performance evaluation of various electronic systems. Second, the test signal is used to replace missing signals in systems being analyzed. There are various types of pulse signals but most often the rectangular pulse shape is used. The construction of various types of pulse generators depends mainly on the generated pulse shape and on the frequency range of the generated signal. But several characteristics are common for all types of pulse (and even other types of signal) generators, [1]. First, the frequency of the pulse signal should be well known and stable. Second, the amplitude should be controllable from small to relatively large values. Finally, the pulse signal shape should be known and stable or, sometimes, adjustable.

The amplitude of the pulse generator output signal is most often controlled in steps. There are a few possibilities to control the pulse signal amplitude. Commonly, resistive step attenuators are used [2], [3]. The drawback of such method is relatively large power dissipation in the resistors, especially in pulse generators with large amplitude of the output signal and small matched load resistance. Better way, from this point of view, is to vary the power supply voltage of pulse generating circuits, active signal shapers (electronic switches) or output amplifiers, [1], [4], [5]. The first of these methods is not suitable because this tends to vary the frequency of the pulse oscillator, [1]. Active signal shapers are not always used in pulse signal generators. In this case, the best way of pulse amplitude control seems to be the variation of the power supply voltage of the output amplifier or its final stage.

The designed pulse generator is controlled by a microcontroller which makes it possible to vary the frequency, the duty cycle (pulse duration and pulse spacing) and the amplitude of the output rectangular pulse signal. It is also possible to select number of pulses in a generated pulse group and to use external synchronization of the generator.

2. Pulse Generator Description

Block diagram of the designed pulse generator is in Fig. 1, [6]. It consists of three main parts: control unit, output unit and power supply source. The control unit is based on the 8-bit RISC microcontroller PIC16F876-20 and contains also a keyboard and a display. This unit makes it possible to set all the desired timing parameters and to generate control digital signals for the output unit to set the desired amplitude of the output pulse signal. Frequency range of the output signal is from 10 Hz up to 5 MHz. Capture/Compare/PWM (CCP) modules are used as timing circuits for setting the timing parameters of the output pulses. In high frequency end (over 20 kHz) Pulse Width Modulation (PWM) mode of operation of CCP modules is used along with hardware control of the level switching of the microcontroller output, while in low frequency end Compare mode is used. This combination of the two modes has been necessary because no single mode has been able to set the timing parameters in the whole frequency range.

Five modes of timing parameters selection are possible: no timing parameters selected (DC output), period and pulse duration, period and pulse spacing, pulse duration and pulse spacing, frequency and duty cycle. After the timing parameters are entered, the microcontroller calculates the necessary parameters and sets the timing circuits according to the calculated values.

Timer0 module timer/counter is used to count the selected number of pulses in case a group of pulses has been selected to be generated. It is possible to generate up to 256 pulses in the group.

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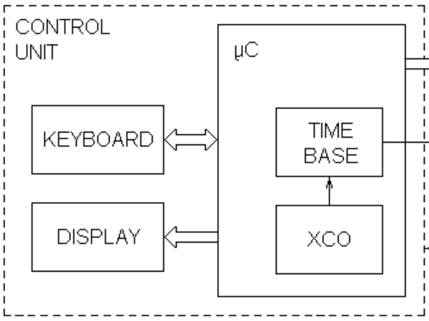

Fig. 1. Block diagram of the designed pulse generator.

The output unit must deliver the output rectangular pulses with the desired amplitude and to further shape the edges of these pulses. The rise and fall time of the pulses are less than 20 ns in the whole frequency range. Only for the amplitudes less than 0.2 V these timing parameters are longer. The output resistance of the generator is 75 Ω. The amplitude of the pulses can be adjusted from 0.1 V up to 5.1 V.

3. Amplitude Control

Except for keeping the rectangular form of the output pulses independently of their frequency and amplitude, the output unit is used as the circuit which controls the amplitude of these pulses. Circuit diagram of the designed output unit is in Fig. 2, [6], [7]. The idea is that the output voltages of two transistor stages with equal configuration, equal circuit elements and the same power supply voltage are equal. After the amplitude is entered into the microcontroller unit, the microcontroller calculates the necessary 8-bit control number and sends it to the input of the 8-bit digital-to-analog converter (DAC) IC1. The output current of the DAC is converted to the corresponding voltage by the current-to-voltage converter IC3. Because of the feedback into the inverting input of IC4, the voltage across the resistor R_{11} is the same as the output voltage, V_{oIC3}, of IC3. Power supply voltage of the generator output stage T2, T3 (collector voltage of T2) must be equal to the desired value V_{Cd} (during the pulse duration transistors T1 and T3 are off, the load resistance at the output OUT is supposed to have the matched value $R_L = 75\ \Omega$)

$$V_{Cd} = V_p\left[\frac{R_6}{R_L(\beta_2+1)}+2\right]+V_{BE2} \tag{1}$$

where V_p is the amplitude of the output pulses at the output OUT, β_2 is short circuit current gain of T2 and V_{BE2} is the base-emitter voltage of T2.

From equation (1) it is evident that the power supply voltage V_{Cd} of T2 and T3 is not the same as the desired pulse amplitude V_p. This is the reason why transistor T4 was used to set the correct value of the power supply voltage V_{Cs}

$$V_{Cs} = V_{oIC3}\left[\frac{R_9}{R_{11}(\beta_4+1)}+2\right]+V_{BE4} \tag{2}$$

where β_4 is short circuit current gain of T4 and V_{BE4} is the base-emitter voltage of T4.

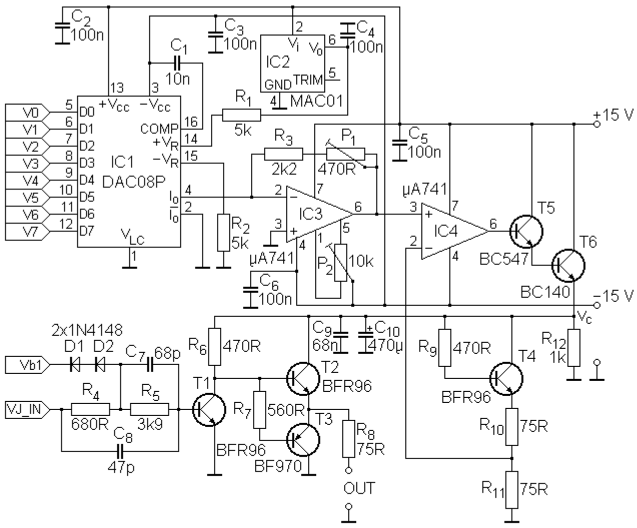

Fig. 2. Circuit diagram of the designed output unit.

Comparison of equations (1) and (2) shows that V_p will be equal to the adjusted value V_{oIC3} only if $R_9 = R_6$, $R_{11} = R_L$ and the parameters of the transistors T2 and T4 $\beta_2 = \beta_4$ and $V_{BE2} = V_{BE4}$. This fact can be better visible if V_p is expressed from equation (1), and equation (2) is used under supposition that $V_{Cd} = V_{Cs}$

$$V_p = \frac{R_L(\beta_2+1)}{R_{11}(\beta_4+1)}\,\frac{V_{oIC3}\left[2R_{11}(\beta_4+1)+R_9\right]+R_{11}(\beta_4+1)(V_{BE4}-V_{BE2})}{2R_L(\beta_2+1)+R_6} \tag{3}$$

In the constructed instrument the resistance values have been selected to be equal. The problem is with frequency and temperature dependence of the parameters β_2 and β_4. It is necessary to keep the temperatures of both transistors equal. The frequency dependence has been software compensated using a table of correction coefficients in the microcontroller unit. The difference of base-emitter voltages in equation (3) has negligible influence. It has been proved that the influence of different parameters β_2 and β_4 can be reduced if the values of the resistors R_6 and R_9 are small enough, that means if they can be neglected in equation (3).

The driving pulse signal from the time base, Fig. 1, is applied to the input VJ IN. For low amplitudes of the output pulses the driving pulse signal is decreased by the control unit by means of the input Vb1 which is now set to the zero level.

4. Software Brief Description

After the switch on of the instrument the initialization is executed. During the initialization the functions of different parts of the microcontroller are set along with the values of different variables, the display is initialized, the necessary data are displayed and the amplitude entering is activated. Mode 1 of timing parameters selection is a default mode. This means that the period and the pulse duration must be entered. The MODE key is used to change the mode. The values of the entered parameters are confirmed by the OK key.

After the amplitude is entered from the keyboard into the microcontroller unit, the microcontroller calculates the necessary 8-bit control value. Because of high relative error of the amplitudes equal or less than 0.2 V, the software correction loop in the program and a correction table are used. The 8-bit control value is sent via a serial channel USART of the microcontroller and a shift register to the input of the DAC.

From all of the entered timing parameters the software calculates the period and the pulse duration. The period is used to select the mode of operation of CCP modules. According to the entered timing parameters the necessary constants are calculated and entered into the registers in the timing circuits of the microcontroller.

5. Experimental Results

The amplitude error was measured in the DC mode. The relative error of the generated voltage value referenced to the desired value was calculated. In the amplitude range from 0.4 V to 5 V this relative error was less than 0.42 %. The amplitude value can be selected in the range from 0.1 V up to 5.1 V with the step 0.1 V.

The frequency is controlled by the crystal clock oscillator of the microcontroller. The measured frequency difference at 5 MHz was approximately 570 Hz with the instability of the order of units of ppm. The measured value of the rise time of the output pulses was 18 ns but under 1V it depended on the amplitude value. At the amplitude value 0.2 V it was 26 ns. The measured fall time of the output pulses was 21 ns and was independent on the amplitude.

6. Conclusions

The designed and constructed rectangular pulse generator is controlled by the 8-bit RISC microcontroller PIC16F876-20. It enables to set the amplitude of the output pulses in the range from 0.1 V to 5.1 V across 75 Ω load by adjusting the power supply voltage of the push-pull output transistor stage. The amplitude error is less than 0.42 %. The frequency and the duty cycle (or the pulse duration) are adjusted by the timing circuits (timer/counters, registers etc.) of the microcontroller itself so that no other hardware is necessary. The frequency range of the generator is from 10 Hz up to 5 MHz. The measured value of the rise time of the output pulses was 18 ns and that of the fall time was 21 ns. The rise time increases in the amplitude range under 1 V. These parameters are satisfactory in many applications.

Acknowledgements

Research described in the paper was financially supported by the Slovak Grant Agency under the project No. AV 4/0012/07.

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