A PWM modulator for wireless infrared communication

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Abstract—**The modulation scheme to be used in a particular wireless infrared communication system is OFDM (Orthogonal Frequency Division Multiplexing), due to its suitability to achieve high datarates in frequency selective, fading channels. However, OFDM is very sensitive to non-linear distortion and highly power-inefficient. PWM (Pulse Width Modulation) is a more power-efficient modulation scheme which is virtually insensitive to non-linearity, thus allowing the use of e.g. highly efficient laser diodes as light emitters. A combination of OFDM and FM has been proposed in [1] and yielded promising results.**

Here, PWM instead of FM is used. First, OFDM modulation is applied to the information. Then PWM modulation is used to render the signal suitable for transport over a non-linear channel.

In the paper, the PWM modulator system design is presented, the circuit design is described, and measurement results on a discrete-component modulator implementation are discussed.

I. Introduction

In this paper, the design of a PWM modulator for an infrared transmitter in a high-speed wireless infrared link is described. A block diagram of the system is depicted in fig. 1. The link is to be used for the transmission of video data to and from mobile users. To minimize power consumption, it is important to choose an efficient modulation scheme, i.e. one that is capable of achieving bitrates close to the channel limit. One such modulation scheme is OFDM. However, OFDM is very sensitive to non-linearity. High-efficiency light emitters, such as laser diodes, are non-linear, thereby prohibiting the use of OFDM directly. The use of linear devices, such as light emitting diodes (LEDs) on the other hand, increases power consumption and lowers the maximum attainable datarate.

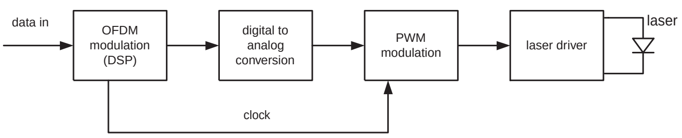

Fig. 1. Block diagram of the transmitter under consideration. The focus is on the PWM modulator.

The goal of this paper is to find a good way to combine OFDM modulation with a non-linear light emitter such as a laser diode.

In literature, several approaches to solve problems of OFDM with non-linearity can be found. An approach suitable for "smooth" non-linearities is the use of coding [1], but the laser does not behave as a smooth non-linearity. Another approach is compensation of the distortion using knowledge on the transfer characteristic [2]. However, the knowledge on the non-linearity of the laser diode is limited and the non-linearity is dynamic as well. An approach more interesting from a complexity point of view is the transformation of the OFDM signal to another modulation scheme which is insensitive to non-linearity before applying it to the laser. In [3] an OFDM signal is FM modulated before transmission, which makes it insensitive to non-linearity. The advantages of OFDM were retained. Here, PWM instead of FM will be used.

The structure of this paper is as follows. In section II, the specifications of the PWM modulator are given and using these, a choice for a particular PWM modulator system is made. In section III, the design of the circuit itself is presented. In section IV, conclusions are presented.

II. Choice of PWM modulator

In this section, the principle of the PWM modulator is discussed and a suitable topology is chosen.

The main specifications for the PWM modulator are

1. time-discrete input signal, value ±1V from a DSP
2. DSP clock signal available, 0-5V signal levels
3. 10^7 PWM symbols per second
4. output signal: a current with value 1mA ↔ "1", 0mA ↔ "0"

A PWM signal consists of pulses that have a *width* which is proportional to the input signal level. This implies that the input signal level should be constant during the period of one PWM pulse, i.e. only discrete-time (sampled) or digital input signals can be converted to a PWM signal. In addition, the PWM pulses

ISBN: 90-73461-24-3

can be at the beginning or end of the symbol period, or they can be centered.

In this section, two ways of generating a PWM signal are discussed. The first one digitally generates a PWM signal. The second one uses a discrete-time version of the input signal to generate the PWM signal. The second option is chosen. Also, a choice is made for a centered PWM pulse, as will be motivated later on.

A. *Direct digital generation of PWM*

In direct-digital generation of a PWM signal, the width of a PWM pulse corresponds to the value of the signal to be modulated. Suppose there are 2^N possible signal levels, i.e. N-bit words. Then each PWM pulse period must be dividable into $2 * 2^N$ subslots to achieve the same resolution as the input signal. This is indicated for $N = 2$ in fig. 2. In the case under consideration, the number of slots per PWM symbol period would be $2 * 2^8 = 512$; combined with 10^7 symbols per second, this would require a digital clock of 5.12GHz. This is an unacceptably high value, especially due to the high power consumption a circuit would have with this clock frequency. For this reason, this option is not considered any further.

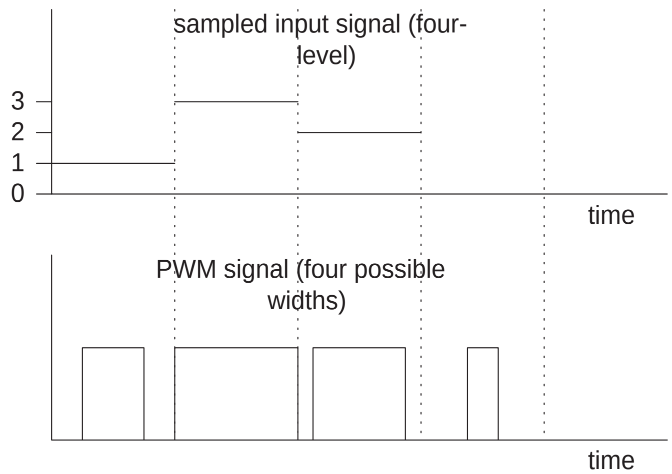

Fig. 2. Direct digital generation of a PWM signal.

B. *Uniformly sampled PWM*

The principal blockdiagram of a uniformly-sampled PWM modulator is shown in fig. 3. To achieve synchronous sampling and conversion, the DSP clock signal is used to generate the carrier wave. A triangular carrier wave is chosen. If a sawtooth carrier wave would be used, the circuits would have to have a high bandwidth as many higher harmonics would still be important. A triangular wave has much less dominant higher harmonics (it already looks sort of like a sinewave). The resulting PWM has centered PWM pulses.

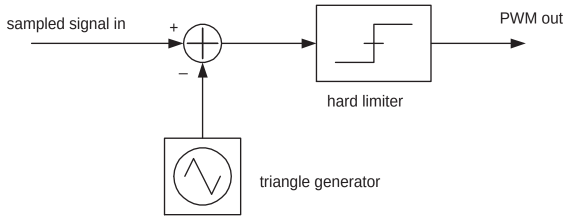

Fig. 3. Block diagram of a uniformly sampled PWM generator.

In constrast to the direct digital generation of the PWM signal, this solution does not require a high-frequency clock signal. Therefore, the power consumption can be expected to be lower and the implementation simpler.

III. Circuit design

In this section, the design of the PWM modulator circuit is described. Mostly, the method first proposed in [4] has been followed. Due to time constraints, the design employs discrete components. It can, however, be ported to an integrated circuit in due time.

Two functions need to be implemented:

- a triangular signal generator
- a comparator

The complete schematic can be seen in figure 5.

A. *Triangular signal generator*

The clock signal of the DSP is a square-wave. A zero-mean square-wave can be converted to a triangular wave by means of integration. Thus, a voltage-to-voltage integrator is a simple option to generate a triangular signal. This integrator, ideally implemented by a nullor, a resistor, and a capacitor, is depicted in figure 4.

The transfer of this integrator is

$$\frac{V_o(s)}{V_i(s)} = -\frac{1}{sRC} \tag{1}$$

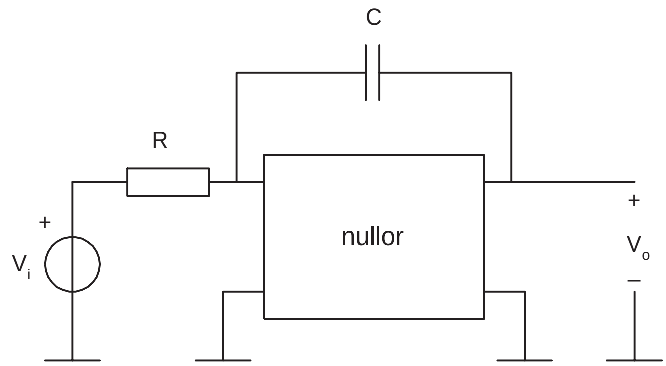

Fig. 4. The voltage-to-voltage integrator using a resistor, a capacitor, and a nullor.

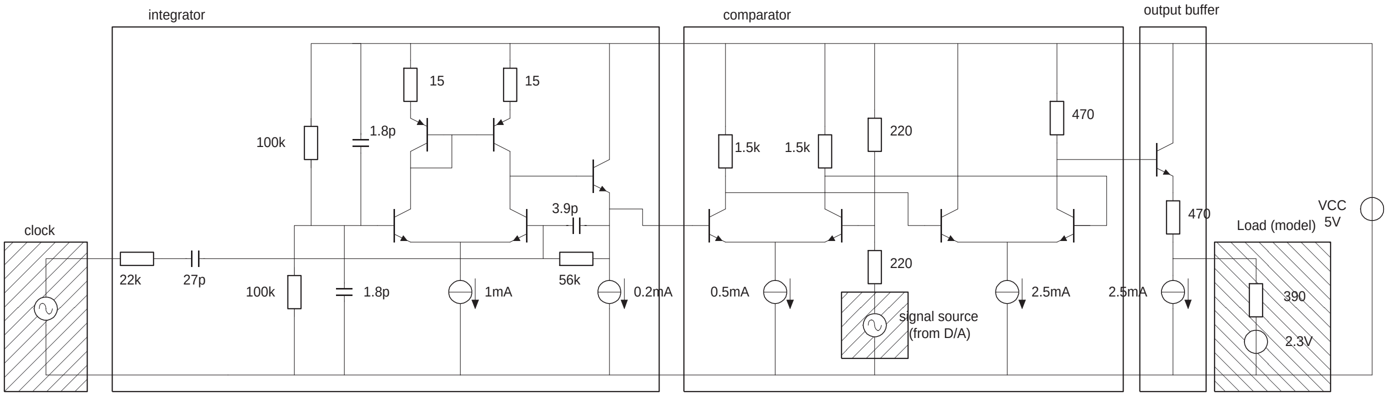

Fig. 5. Total circuit diagram of the PWM modulator.

The frequency of the input signal is 10MHz, and the amplitude of the sampled input signal is 1V; therefore the amplitude of the triangular wave should be at least 1V as well. Then $RC < 62.5$ ns. A value of 22k for the resistor, and 3.9pF for the capacitor have been chosen.

The nullor implementation consists of a differential pair with current mirror and a common-collector stage at the output for extra loopgain. For proper biasing, a resistor has been added in parallel to the integration capacitor. To reject the DC component in the clock signal, a small capacitor has been put in series with the integration resistor. In order to compensate for offset introduced by DC currents through the resistor in parallel with the integration capacitor, the same (signal) resistance has been put in series with the other base of the differential pair.

B. Comparator

The comparator consists of two differential pairs in cascade, and a buffer output stage. To one input, the sampled signal is applied. To the other input the triangular signal generator is connected. The output stage is required to adapt the PWM signal to the laser driver circuit modeled by "load" in figure 5. Due to the buffer stage, a current of either 0 or 1mA will flow through the input of the laser driver circuit.

C. Measurement results

Unfortunately, due to time limitations, no measurement results can be shown. However, preliminary measurements indicate that the circuit is functioning correctly.

IV. Conclusions

In this paper, the design of a PWM modulator for a high-speed wireless infrared link has been presented. It has been shown that direct digital generation of a PWM signal was not feasible, but that a uniformly sampled PWM signal could be generated by using a discrete-time input signal. The modulator has been built and preliminary measurements show promising results.

References

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