Microcontroller Interface for Time to Digital Converter Chip GP2

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Introduction

High resolution time measurement finds application in various science and engineering set-ups. A popular way of measuring time difference between two logic pulses is, using Time to Amplitude Converter (TAC) followed by an ADC. In recent times, time difference measurement based on propagation delay of CMOS inverters has evolved. These CMOS inverters form a long chain, implemented in Time to Digital Converter (TDC) chip [1]. The TDC also contains decoding logic for measurement of time and interface for digital data readout.

We have designed and tested a microcontroller based evaluation circuit for a commercial TDC chip (GP2 Make: ACAM) [2]. We present in this contribution overview of microcontroller hardware-firmware interface for TDC-GP2 and its measurement results.

TDC Chip GP2

This TDC measures time difference with a resolution of 65ps. It has two measurement ranges 0 to 1.8µs and other 500ns to 4ms. The time difference is given by the combination of coarse counts and fine counts. The coarse count is measured by the reference clock and the fine counts by the CMOS inverters (see Fig. 1). TDC gives result in 32 bit fixed point format containing 16 bit integer and fractional part each. The ratio of fine counts difference to calibration count difference takes care of the variation in delay of CMOS inverters due to temperature. Time difference is calculated by:

$$TD = T_{Ref} \times (Cc + (Fc1 - Fc2) / (Cal2 - Cal1))$$

Where, T_{Ref} is time period of ref clock used (250 ns), Cc is coarse counts, Fc1 and Fc2 are fine counts Cal2 and Cal1 are used for calibration (see Fig 1, 2). TDC configuration and data registers are accessible to any microcontroller via Serial Peripheral Interface (SPI) protocol.

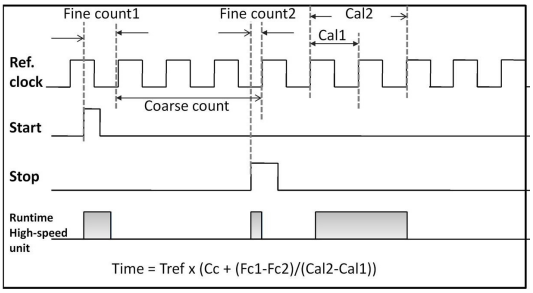


Fig. 1 Measurement Principle

Hardware Interface

TDC is connected to a microcontroller (P89V51RD2) [3] as shown in Fig. 2. TDC can be configured to measure time difference between start, stop1 and stop2 signals. The microcontroller reads TDC via four SPI signals and presents the result to hyper terminal of PC. In actual set-up more than one TDC can be part of SPI bus with individual slave select.

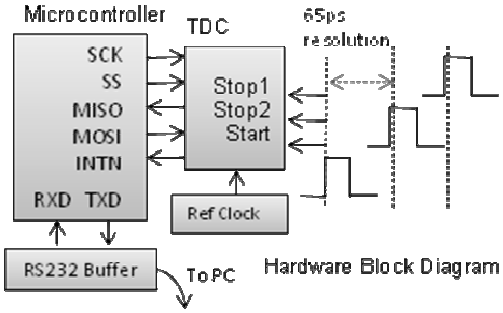


Fig. 2 Hardware Block Diagram

Microcontroller Firmware for TDC Readout

The TDC measurement was done using flow chart presented in Fig 3. The configuration

is done for selection of measurement range, calibration or no calibration, time differences to be measured, number of hits expected etc. Initialization of TDC is done by sending an op-code, which arms the TDC to accept new start stop pulses for measurement.

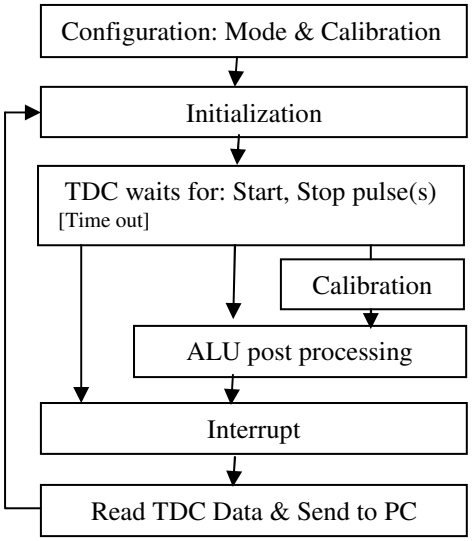


Fig. 3 Measurement Flow

TDC waits for start and stop pulses. It generates interrupt when ALU is ready with data or if no stop pulse arrives (within measurement range limits) after the occurrence of start pulse. Upon interrupt microcontroller reads TDC data, calculates time difference and sends result to PC. TDC now needs to be reinitialized to accept new inputs.

While communicating over SPI bus microcontroller has to generate slave select, send op-code byte followed by this are more read or write byte transfers. The SPI master logic in microcontroller takes care of SPI clock generation and data transfers.

Measurement Results and Conclusion

To test the TDC a step input was generated after initializing the TDC, by the same microcontroller which initializes and reads the TDC. The step input is start, this is delayed by two not gate to generate stop1, stop1 is delayed by two not gates to make stop2.

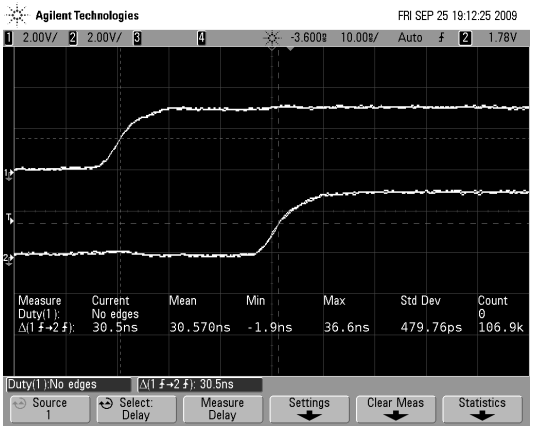
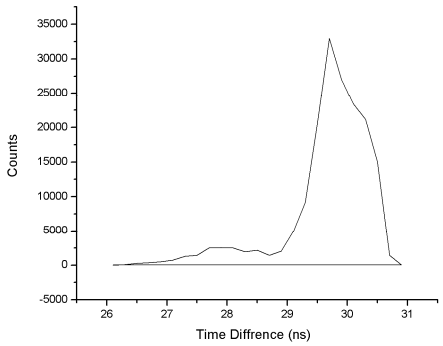


Fig. 4 Test Measurement Waveforms

The test results are shown in the oscilloscope waveform captured (Fig. 4) and frequency distribution of time difference readings captured on hyperterminal (Fig. 5)



The preliminary results shown above lack a precise test input. A circuit based on temperature compensated oscillator with complementary output can be a more reliable test input.

References

[1] Chorng-Sii Hwang, Poki Chen and Hen-Wai Tsao "A High Precision Time To Digital Converter Using a Two-Level Conversion Scheme." *IEEE Trans. Nucl. Sci.* vol. 51, No. 4, pp 1349-1352 AUGUST 2004

[2] TDC GP2 Datasheet.

[3] Microcontroller P89V51RD2 Datasheet.