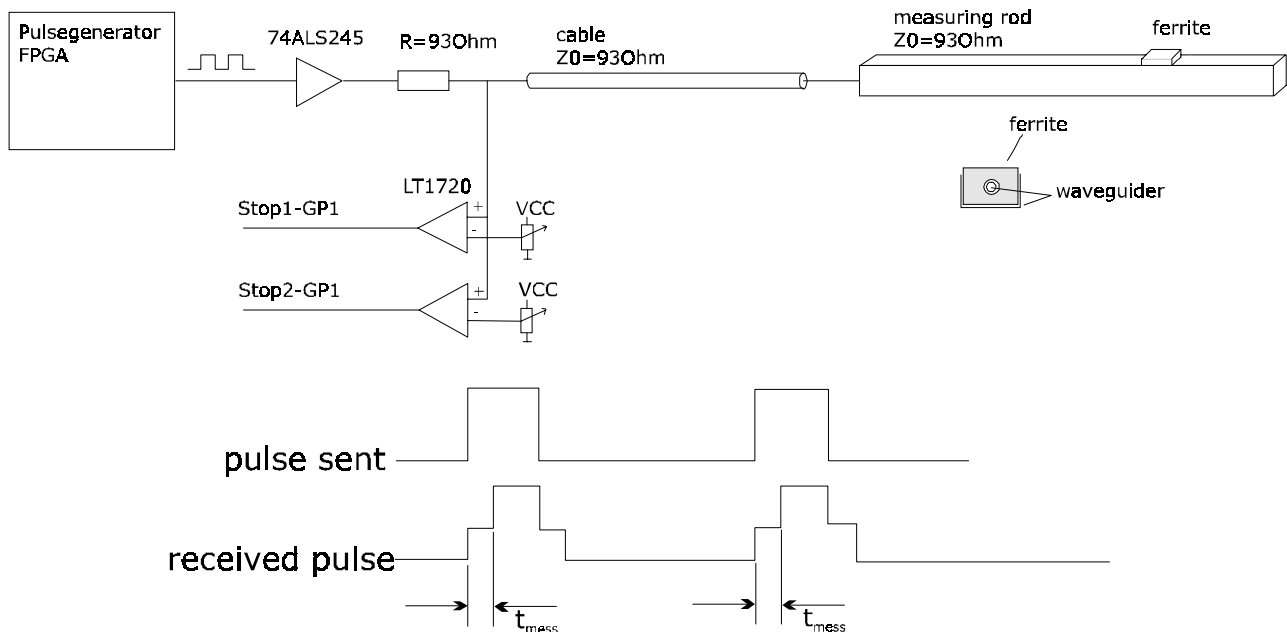


## Position Measurement using Reflected Electromagnetic Waves

In several positioning tasks already today TDCs (Time-to-Digital Converters) are in use. A typical application are laser rangefinders based on measuring the time-of-flight of a laser pulses. We introduce a new simple method of measuring the position on a waveguide with a precision of approx. 0,1mm. The advantage of this method is that all the electronics can be integrated into a single digital ASIC.

Figure 1



### The Measuring Principle

Figure 1 shows the setup. The measuring rod is realized as a waveguide with defined real resistance. Placed on the rod there is a movable body that introduces a strong variation of the impedance. Experiments showed that highly permeable ferrite material is the best choice.

A rectangular pulse is sent to the waveguide. The driver has to be terminated with the correct impedance. At the position of the movable body the biggest part of the pulse will be reflected and travels back to the sender. The travel time of this reflected pulse is measured with a TDC. The time interval is a measure for the position.

To avoid disturbing non-linearities, it is recommended to have some cable between the electronics and the measuring rod. This cable must have the same impedance as the rod. Otherwise the start slope and stop slope are together too close.

### Requirements for the TDC

The travelling speed of the pulse nearly reaches the speed of light. A variation in position of about 1mm corresponds to a time difference of 6ps. To

achieve a resolution of less than 100µm, it is necessary to reduce the standard deviation of the time measurement down into the range of femto-seconds. This will not be possible with a single measurement but by averaging over many measurements. Therefore it is necessary that the TDC offers the correct statistical behaviour. Using TDC-GP1 in Resolution Adjust Mode this is guaranteed. In this mode the standard deviation can be reduced down to 150fs.

In an experimental setup of the length measurement system we worked with 100,000 samples and achieved a standard deviation of 500-600fs, which corresponds to resolution in position of < 100µm.

### Achievable Precision

The noise caused by quantization effects can easily be reduced by averaging. The final standard deviation depends on two factors:

- offset drift
- achievable sampling rate

## Offsetdrift

Experiences from TDC-GP1 show, that with careful design the offset drift over the the total temperature range will be in the range of 2-3 ps. If the temperature varies not more than 20°C after offset correction, the offset drift will be in the range of femtoseconds.

## Sampling Rate

The maximum measurement rate of TDC-GP1, operated in resolution adjust mode, is about 2,5 million measurements per second. The standard deviation for a single measurement is about 0,8 LSB = 200ps. Single shot resolution and max. measurement rate define the limits of the range in which the user can vary between update rate and precision via sampling rate. In our experimental setup, where we had 500fs resolution, the update rate was about 25 per second.

## Outlook

The values mentioned above are based on measurements done with TDC-GP1. Building a new special TDC on the basis of modern semiconductor technology, it will be possible to considerably improve the performance. The standard deviation

of TDC-GP1 is typ. 200ps in single shot. Using newest CMOS process technology and optimized design this can be reduced by a factor of 10. Keeping the resolution of the length measurement system the same, the update rate will be increased by a factor of 100.

## Advantages

The entire electric circuit is digital. It easily can be integrated into a single chip. This allows to realize a very compact and cost effective solution for the sensor. The current consumption can be reduced to a few mA, depending on the update rate.

The method is also suitable for measuring at long distances (30m and more).

The information provided herein is believed to be reliable. However, acam-messelectronic assumes no responsibilities for inaccuracies or omissions. acam-messelectronic assumes no responsibility for the use of this information, and all use of this information shall be entirely to the user's own risk. No patent rights or licenses to any of the circuits described herein are implied or granted to any third party. acam-messelectronic does not authorize or warrant any acam-messelectronic product for use in life support devices and/or systems.

2nd Release April 2001