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# A Time-to-Digital Converter Based on a Digitally Controlled Oscillator

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Time measurements play a crucial role in trigger and data acquisition systems (TDAQ) of High Energy Physics (HEP) experiments, where calibration, synchronization between signals and phase-measurements accuracy are often required.
Although the various elements of a time measurement system are typically designed using a classical mixed-signal approach, state-of-art research is also focusing on all-digital
architectures. Mixed signal approach has the advantage to reach better performances, but it requires more development time than a fully-digital design. Moreover, the porting of analog IP blocks into a new technology typically requires a significant design effort compared with digital IPs.
In this work, we present a fully-digital TDC application, based on a synthesizable DCO, where the TDC measures the phase relationship between a timing signal and a 40 MHz reference clock. The DCO design is technology-independent, it is described by means of a hardware description language and it can be placed and routed with automatic tools.
We present the TDC architecture, the DCO performances and the results on a preliminary
implementation on a 130 nm ASIC prototype, in terms of output jitter, power consumption,
frequency range, resolution, linearity and differential non-linearity.
The TDC will be used in the new readout chip that is under development for the Muon detector electronic upgrade in LHCb experiment at CERN. The TDC presented in this paper has the fundamental task of measuring the phase difference between the 40 MHz LHC machine clock and a digital signal coming from the muon detector, in order to allow the phase shift of the detector signal according to the required resolution of the experiment.

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