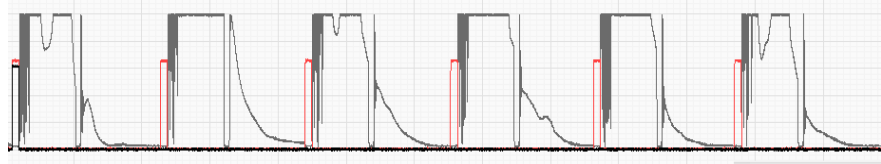
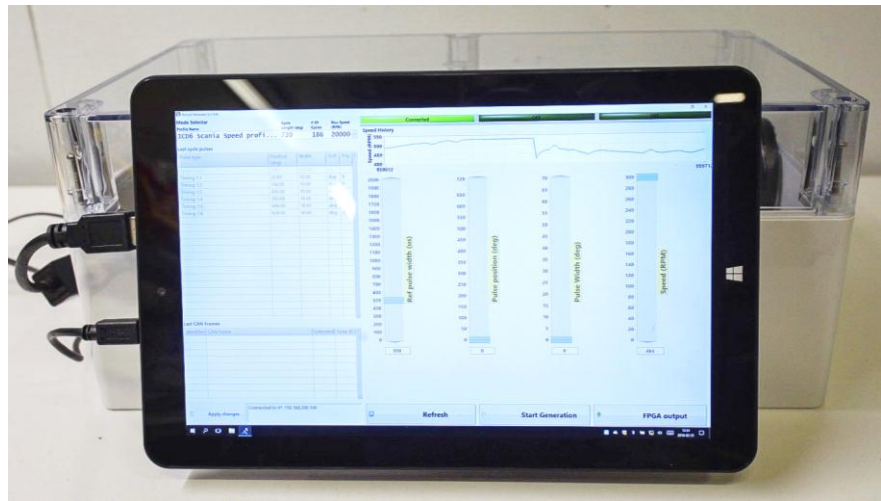
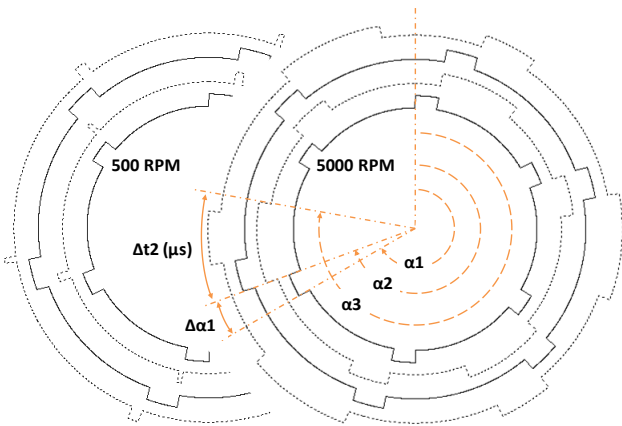


High Speed Stimuli Generator

for Engine Ignition systems



Abstract

WireFlow helped SEM (Svenska Elektromagneter) to develop an advanced, high performance and highly configurable Stimuli Generator (STIG) for up to 12 cylinder ignition systems. The system was built using National Instruments cRIO hardware and LabVIEW/LabVIEW-RT and LabVIEW-FPGA.



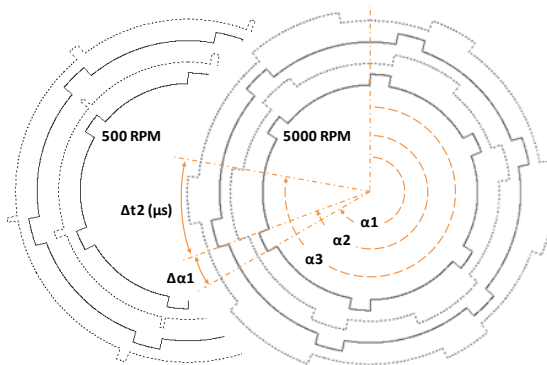
The system can define stimulus for each cylinder in terms of ignition pulses, trigger pulses as well as engine speed and analog simulation data – everything relative to the start of an engine cycle (Crank Angle Degrees – CAD). The width of any digital pulse can be set in 0.01 CAD or in 0.1 μs steps resolution. Engine speed can be varied between 0-20 000 RPM, either as a predefined speed profile or manually when the system is running.

Challenges

SEM is one of the world's leading producers of electronic ignition systems and engine control systems. SEM develops and produce high-end ignition systems for a variety of engines, ranging from one cylinder engines for chainsaw motors to big gas engine systems with 8 cylinders or more.



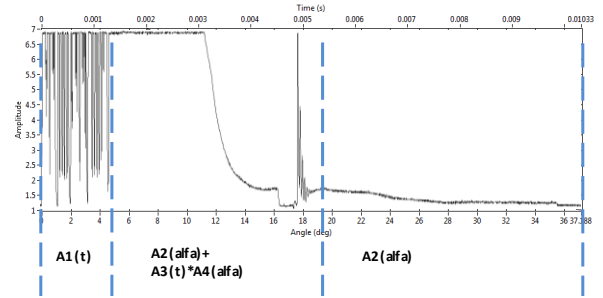
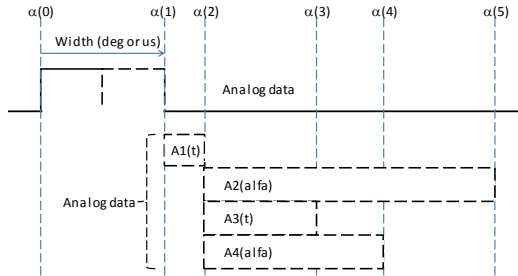
During development it is important to be able to exactly control all parts of the ignition, like spark position and duration for each cylinder for a number engine cycles – representing a specific startup behavior or mimicking a faulty behavior.



One of the tricky parts is that spark duration can be given in CAD (0.01 degree resolution) or given as a fixed time (0.1 μs) depending on engine type, whereas spark position is always given as a position (CAD) in the engine cycle. In the figure to the left a fixed configuration for four DO channels are shown for two different engine speeds. The solid pulse trace is a signal with all

data given in CAD in the engine cycle, and the dashed trace displays a situation where the pulse width is given in μs . To find the end of a pulse the system has to handle both pure CAD positions ($\alpha + \Delta\alpha$), as well CAD position with time delays ($\alpha + \Delta t$) simultaneously. Because of possible speed changes, the system has to continuously recalculate the end of all pulses where width is given in μs . Because the pulse position and width might not be fixed, the system must also constantly validate that two pulses is not overlapping (e.g. if speed is high enough). The engine speed must also be settable at a specific CAD (in 0.01 steps) with a RPM resolution of 0.01.

To further add to the complexity, the system must continuously calculate analog data that are a combination of time- and CAD-based data, to simulate the engine.

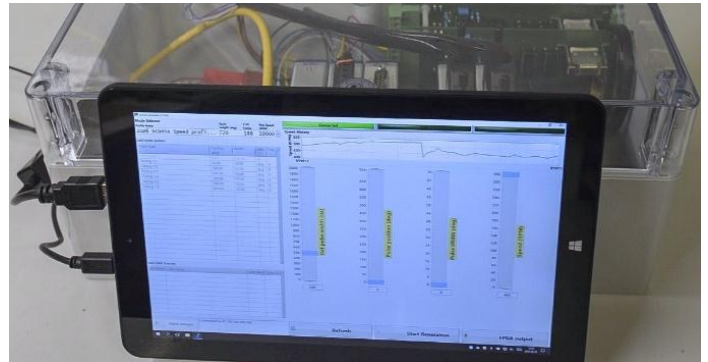


Since the CAD domain analog data is defined with 0.01 CAD resolution it means that the system has to be able to constantly stream 72 000 data points (one cycle) at all speeds.

At 20 000 RPM this translates to ~12MS/s. With 8-byte values, this corresponds to 96MB/s (192MB/s in total) per analog channel that is streamed, calculated and written to the AO outputs. The picture above summarizes the complex generation for analog output data, where each angle $\alpha(i)$, except $\alpha(0)$, can vary depending on the engine speed changes and the definition of engine cycles.

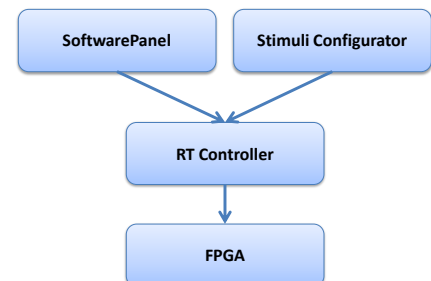
Solution

Using LabVIEW and a high end cRIO from National Instruments™ WireFlow created a system that allows the technicians at SEM to select predefined engine cycles using a touch-screen. The user can also manually control all aspects of the ignition cycle, including position and duration of each ignition pulse as well as the reference pulse using different slider bars in the GUI. It is also possible to manually change the RPM value while maintaining the pulse characteristics, i.e. the position and duration regardless if it is given in time- or CAD-domain.

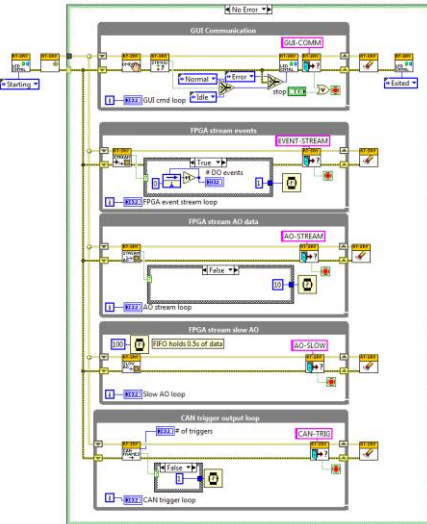


The system consists of four main LabVIEW components,

- The FPGA
- The RT Controller
- The Runtime control GUI (pictured above)
- The Stimuli Configurator GUI



In the offline Stimuli Configurator GUI technicians defines a specific engine cycle with a unique speed profile. The profile is transferred to the cRIO as a TDMS file and played back using the Runtime Control GUI.



The main focus of the RT controller is to continuously stream the events that define the pulses, speed etc. to the FPGA, and to stream all analog and CAN data that can be triggered by the pulses and which are defined in the Stimuli Creator GUI and stored in the TDMS file.

It also handles all commands sent from the GUI, e.g. pulse characteristics and speed. It also sends status to the GUI, to inform the user about the current speed and the current cycle.

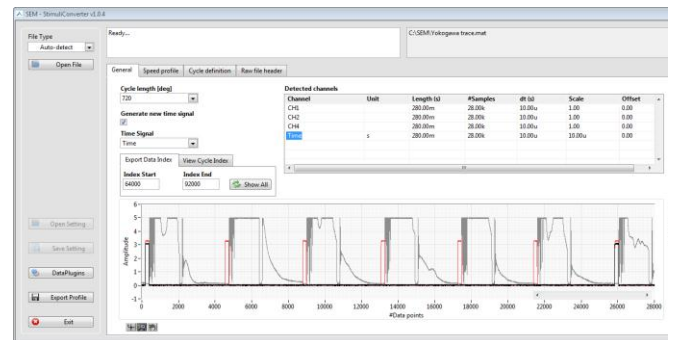
The cRIO-FPGA is the heart of the system and does all the heavy lifting, generating up to 31 channels of digital pulses, where each channel

contains up to 13 pulses per engine cycle. It also handles the analog data that the RT process streams to the FPGA at a maximum rate of 192MB/s all triggered from the defined DO pulses. To be able to meet the requirements for both digital and analog I/O, all data has to be calculated in a Single Cycle Timed Loop (SCTL).

Outputs can then be generated with the required output accuracy of 0.1µs for digital pulses, and better than 0.01 CAD resolution for angle domain data.

Running the system at full load, i.e. 20 000 RPM with 31 channels with pulse trains and maximum analog data stream, still only uses ~35% of the cRIO CPU.

In addition to be used during development the system can also be used to playback customer recorded data or to validate scenarios recorded on the lab. Because different customers use different types of instrument to record the data WireFlow developed a versatile tool that can import many different data format (e.g. Yokogawa *.mat files) and convert the data to the Stimuli Generator TDMS format. The tool extracts speed, reference pulses as well as timing and analog data and STIG can then reproduce the recorded data on the test bench.



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