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# A breakthrough in high-speed digital eddy current testing technology

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**Abstract**

Legacy eddy current devices largely depend on an analog signal processing chain. Severe limitations towards speed, multiplexability and accuracy are imposed by these analog front ends. A new generation of eddy current testing instruments is presented, which alleviates these restrictions by using a FPGA-based fully digital signal processing chain. Speed, accuracy and the ability for complex an fast multiplexing operations are only some of the benefits reaped from using this novel approach. High speed applications, such as real-time inspection of railway tracks at speeds above 100km/h, inspection in high speed production lines like in wire production, high speed sorting and high speed probe multiplexing become possible.

**Keywords:** NDT, Eddy Current, High-Speed

## 1 Device Architecture

### 1.1 Overview

The Architecture of eddy current flaw detectors evolved from the complete analog design of the early days of this technology towards the partially digital instruments which are commonly in use today. They encompass an analog measurement front end and digital control systems and microcontrollers for parametrization, user-interface and data acquisition purposes. Only recently, devices are emerging which use an almost fully digital approach, where for low frequencies, even the demodulation stages are digital and for higher test frequencies all the signal processing after the demodulation is carried out digitally.

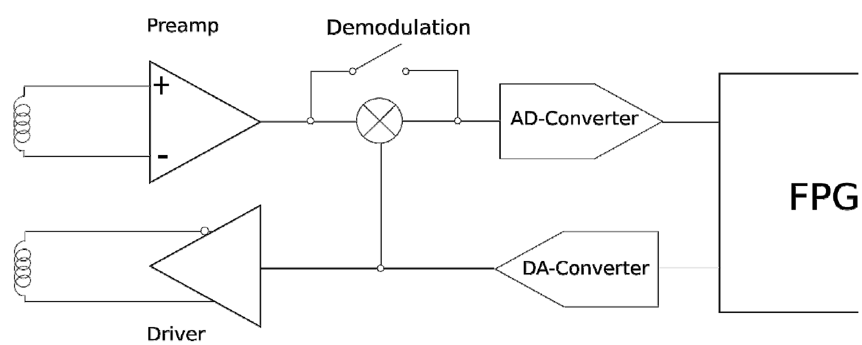


*Figure 1: Block Diagram of one Eddy-Current Channel*

Most of these devices employ digital signal processors (DSPs) to do signal processing and conditioning. In contrast, the presented new device family is using modern field programmable gate arrays (FPGAs) for all signal generation and processing purposes. While being significantly more expensive to design with compared to DSP systems, FPGAs can perform many signal generation and processing tasks simultaneously. Due to the fully programmable nature of the devices, even new demodulation schemes or other algorithmic improvements in the signal generation chain can be implemented without changing the hardwired electronics of the device.

# 1 Applications

## 1.1 Railway tracks

Railway tracks are commonly tested for faults during production, during use and while reworking.

In-line testing in railway track production facilities needs to cover all critical surface areas of the track profile in the head and the foot region. Due to the shape of the track profile, rotating probes can not easily be deployed for these tests. Here, fast multiplexing of up to 240 probes, in groups of 16 probes per channel, enables perfect coverage of the critical surfaces of the track while maintaining test speeds of up to 2 meters per second while looking for defects at an lengthwise resolution of a tenth of a millimeter. Figure 2 shows test results of a laboratory setup evaluating the fitness of the system for this application.

*Figure 2: Push Trolley for Manual Railway Inspection*

A slightly scaled down system can be used for manual inspection of installed rails using a trolley which is pushed by an inspector. Here, the speed of 2m/s is still sufficient, so fast multiplexing can be used. Here, a key benefit is that a lightweight single channel system can be used to inspect a large rail area, since weight and power consumption is of primary concern in this application.

High speed inspection of installed rails using an inspection train (usually in combination with ultrasonic inspection) can not use multiplexed sensors. Here, the massive parallel data processing power of the System is used by installing up to sixteen EC-Channel modules into one device, each carrying its own FPGA and being capable of full real-time testing and data acquisition at 100 kHz LF Bandwidth with a sample rate of 250 ksps/s per channel. This amounts to a sum sample rate of four megasamples per second at a sample size of four bytes of xy-data and four bytes of status information, delivering a data rate of 32 megabytes per second. Furthermore, online data evaluation and compression algorithms can be implemented inside the FPGAs, possibly reducing the amount of data which has to be stored.

### 2.2 Corrosion testing in aircrafts

In aircraft inspection, low frequency array technology is the key to testing structural components for hidden corrosion. Since a high penetration depth is necessary, the inspection frequencies have to be in the 10 kHz range or below. Still, array probes have to be used to cover as much surface as possible in a short time. Here, the FPGA based approach makes it possible to still attain fast multiplex rates up to 5000 scans per second over an array of 16 probes at an inspection frequency of 5 kHz. This opens up new possibilities in high speed corrosion testing using lightweight, hand held instruments.

### 2.3 Tubes and wires

In the tube and wire industries, parallel high speed testing of several production lines is often necessary. The fully parallel nature of th architecture employing fully self contained channels makes it possible to test at full speed at as much as 15 production lines using only one instrument. Fault information can be selectively recorded and marking equipment can be directly connected to the instrument.

### 2.4 High speed sorting

Multi-frequency sorting applications can make use of the internal parameter multiplexing engine to do sorting at up to 64 multiplexed frequencies while using only one and a half sine wave of each frequency slot. Advanced demodulation schemes applied in the FPGA yield excellent signal to noise ratios and the absolute, drift-free stability of a fully digital system. As in most applications, eight frequency sorting seems to be sufficient, the additional multiplex channels can be used to switch instantaneously between up to eight sets of parameters and gate settings to accommodate production lines where different types of parts are tested in succession. In one Device, up to 16 fully parallel sort channels can be installed.

## 2 The Future

The possibilities and flexibility of the new FPGA based systems are far from being fully exhausted today. Due to the ultimate programmability of the FPGA signal generation and processing chain, things like impulse eddy current, overtone detection, Fourier analysis and other advanced methods lie in reach of the new system. It lends itself as an ideal system to quickly test new approaches and ideas without having to build special hardware. By using different analog front ends, even ultrasonic testing, Giant Magnetic Resonance testing and other, non eddy-current techniques could be possible.

## 3 Conclusion

The presented system possesses many desirable features which open up new opportunities for eddy current testing. Key features are high speed testing and high speed multiplexing, additionally advanced demodulation schemes can be used to further increase testing speed and accuracy.