# Electronics dedicated to ultrasonic waves SHM

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Structural Health Monitoring (SHM) is an embedded Non Destructive Testing (NDT) technique that requires the merger of different engineering disciplines such as signal processing, electronics, acoustics, and mechanics. One of the most commonly used detection technique is to emit and receive ultrasonic waves with piezo-electrical transducers attached to the structure. The propagation of the wave is analyzed to evaluate the presence of defects inside the structure. This ultrasonic detection method is particularly appropriate to monitor large structures whose systematic inspections are mandatory but costly, such as aircrafts, spacecrafts, boats, bridges, cables, pipes, etc...

Cedrat Technologies has an extensive experience in the field of piezo-transducers and their related electronics (driving, sensing, controlling), which served as a basis to develop SHM-dedicated electronics solutions. The proposed solutions consist in driving and sensing electronics, ranging from the pure analog rack to the fully programmable solution delivered with Graphical User Interface (GUI).


*Fig. 1: 8-channel laboratory rack with fully featured SHM channels (DC power supply, emission, reception)*

## HARDWARE REQUIREMENTS FOR SHM APPLICATIONS

SHM is a rapidly growing field with many different applications, with each of these applications requiring a specific hardware depending on parameters such as:

- Material on which the piezo-patches are attached.
- Size of the structure and required distance of propagation.
- Type of defect to be detected.
- Detection strategy (for instance phased-array technique)
- Integration level of the solution: from laboratory proof of concept to complete embedded detection system.

Based on these inputs, CTEC is able to analyze customer needs in order to provide a complete hardware solution, with different levels of customization.

Some of the hardware characteristics that can be adjusted to fit with the application are:

- Type of piezo-patches (capacitance and operating voltage).
- Number of piezo-patches and emission/reception channels.
- Amplifier characteristics (gain, bandwidth, signal to noise ratio, variable gain option, etc)
- Conditioner characteristics (bandwidth, signal to noise ratio, etc)

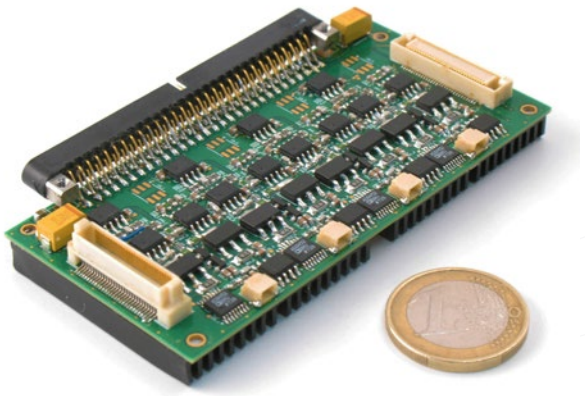

*Fig. 2: 4-channel fully featured (pulse-echo) SHM embedded platform*

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## WORKING PRINCIPLE & TECHNOLOGIES

From the hardware point of view, the structure of a fully featured SHM channel suited for piezo-patches is described on figure 3. This channel is typically composed of three analog functions:

- A power amplifier to drive the piezo-patches in order to emit the acoustic waves on the structure.
- A conditioner to be able to read the acoustic waves incoming on the piezo-patches.
- A commutation function to be able to switch the piezo-electrical patch between emission and reception modes.

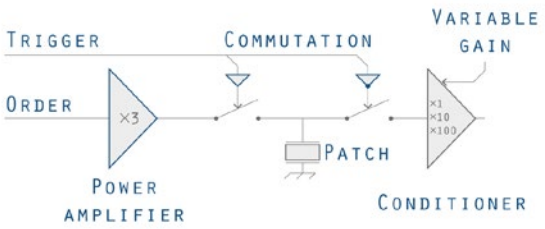


*Fig. 3: Structure of a SHM channel*

The power amplifiers offer an unloaded wide bandwidth of 2.5 MHz with a current limit of 0.5 A peak, in order to reach the ultrasonic range and feature a high SNR(more than 70 dB). They are specifically designed to drive capacitive loads, since the piezo elements have a capacitive behaviour. In addition they offer different output voltages depending on the type of piezo-ceramics used.

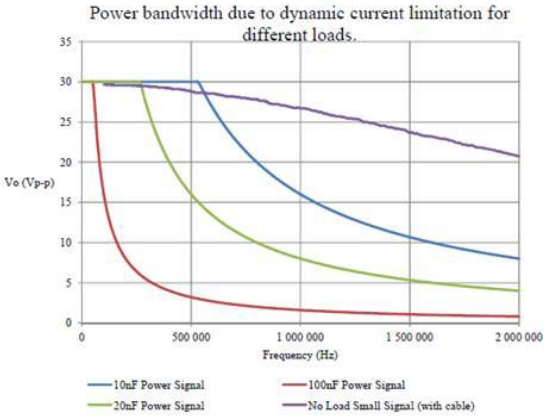


*Fig. 4: Power bandwidth due to dynamic current limitation for different loads*

The conditioners offer a wide bandwidth to match the amplifier bandwidth and a very high SNR to be able to receive weak acoustic waves. If required the conditioners can feature a variable amplifier gain which is particularly interesting for laboratory setups.

The switching function, allowing pulse-echo technique, offers the possibility to switch the patch between the two modes (emission or reception). This allows to emit a signal with a patch and to monitor the echo of the signal on the exact same patch, keeping the number of patches, cables and board connectors to a minimum. It is thus a cost effective solution that reduces the complexity of the system. In order to take advantage of this function, the commutation time has to be very short in order to be able to catch the echo (less than 1 µs). An example of emitted, reflected, and transmitted signals is shown on figure 5:

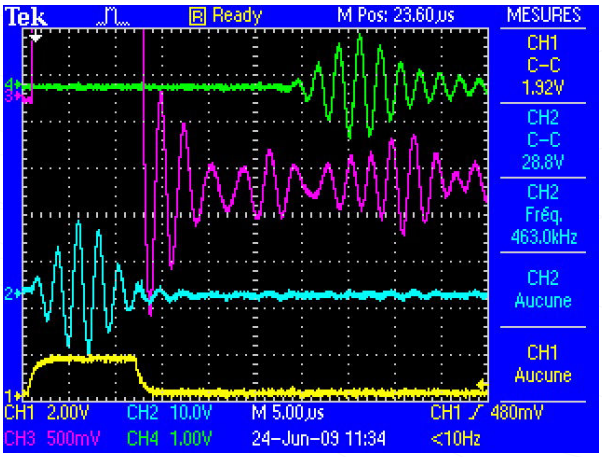


*Fig. 54: [CH1] Pulse-echo command (yellow), [CH2] emitted signal (blue), [CH3] reflected signal, i.e echo (purple), [CH4] transmitted signal (green)*

In addition to the previous functions, some generation and sampling functions are required to send the orders, and to record the received signals for analysis. This could be done with regular generators and with oscilloscopes or acquisition platforms. However, SHM applications often require specific equipments since multiple channels are required, as well as very high refresh rates. In order to reduce the time for acquisition and the complexity of the setup, dedicated generation and acquisition platforms are recommended. These platforms feature:

- Several synchronized input or output channels with refresh rates up to 10 MSps.

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- High resolution to comply with the high SNR requirements of the SHM applications.
- Arbitrary generator channels so that the user can generate any waveform desired, to fit with his application.
- Interface with computers and dedicated GUI for loading the signals to be generated and recovering the recorded data.

## EXAMPLES OF CEDRAT TECHNOLOGIES SOLUTIONS

Depending on the customer's requirements, Cedrat Technologies can build the desired solution, which can range from a pure analog laboratory rack to a fully programmable solution with GUI. Examples of different electronic designs are presented on figures 6 to 8, to show the broad range of possibilities offered by Cedrat Technologies. The customer can be delivered with a complete emission and reception solution or with a partial solution if the user chooses to manage the rest of the detection system.

*Fig. 6: 36-channel emission unit with ±15V output voltage for applications in the 100-1000kHz range*

## KEYWORDS

SHM, NDT, Piezo-Electrical Patches, High Frequency Power Amplifier, Low Noise Conditioner, Arbitrary Waveform Generator.

*Fig. 7: 18-channel emission unit with ±200V output voltage for applications in the 25-40kHz range*

*Fig. 8: 12-channel arbitrary generator with 10MSps sampling rate and 14bits resolution and dedicated GUI for configuration.*