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HCAL 2-channel LED calibration prototype

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Abstract

The next generation of the HCAL prototype – technological prototype aims at the development of technologies which can be used at the final detector. Also it should overcome problems encountered in the exploitation of the physics prototype. In this note a new version of the LED driver for the calibration of the technological HCAL prototype is proposed.

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Introduction

This Memo deals with our new work in the field of calibration, control and monitoring system for the new version of the CALICE prototype. The older version of this system was developed and produced in the Institute of Physics ASCR, Prague and built into the HCAL physics prototype. It was tested in DESY and CERN and we use it as a base line equipment. The new version tries to get rid of the disadvantages of the older version and takes into account a bigger size of the technological prototype.

1 Calibration board

1.1 Overview

The last calibration system used at the HCAL physics prototype and known as a Calibration and Monitoring Board (CMB), has a variety of flexibility like pulse-width setting of fast rectangular LED pulses. It pays off to a smaller electromagnetic compatibility, relatively high power consumption, higher cost and complicated electronic circuitry. So we have started a development of a new more dedicated system. The new control system is similar to the system of CMB and we call it CQLD system (Calibration Quasi-resonant LED Driver board). It is fully controlled via CANBUS and the onboard microprocessor. It reads the temperatures, voltages and other hardware parameters and controls switching of separate LED channels and sets the output parameters of the light pulses. The amplitude and the rate of optical pulses is possible to be set from an external computer via CANBUS. The stability of the output calibration optical pulses can be monitored by the feedback from PIN photodiodes. The principle of the whole system is shown in the Fig. 1.

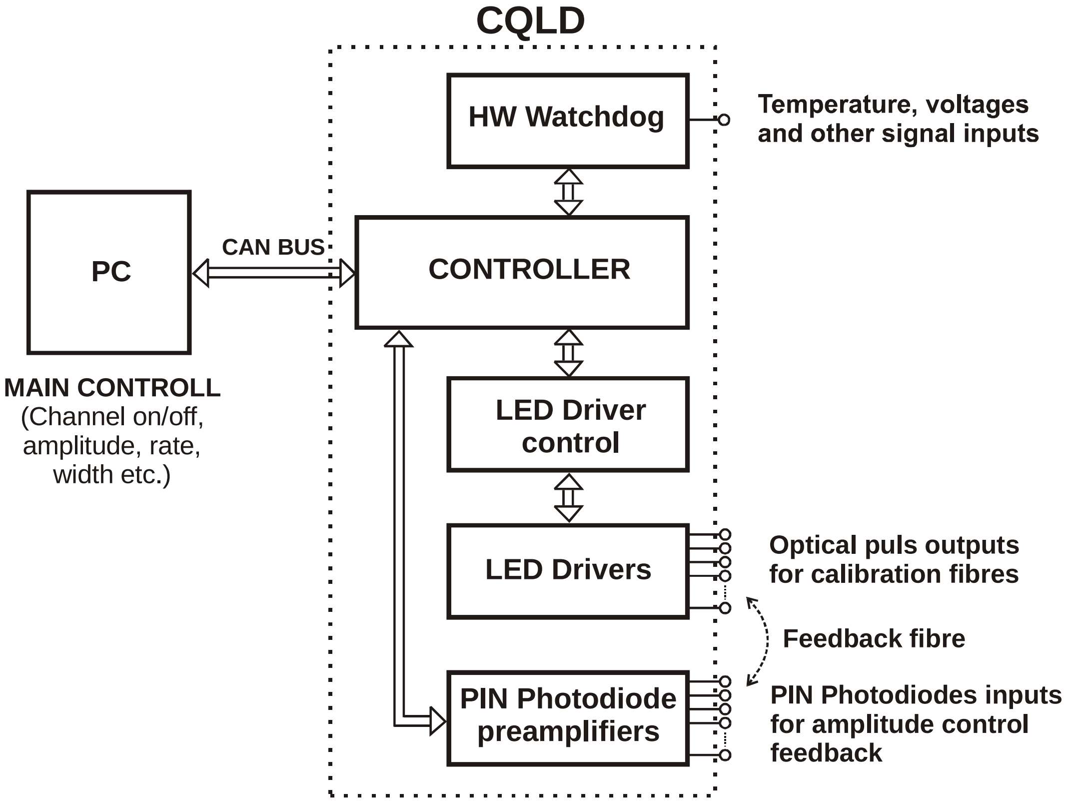

Fig. 1 - A principle diagram for Calibration Quasi-resonant LED Driver

The whole system communicates with a PC via CANBUS. This interface sends the control data to the microcontroller and reads the output data from it. The microcontroller then switches on a separate LED driver channels, sets the amplitude of the output pulses. This information is sent to the LED driver channels control circuit where it is transformed from the digital to the analog form and the amplitude of optical pulses is set. In this memo we concentrate on the new part of the system – the quasi-resonant LED driver.

1.2 New pulse generator

The main difference compared to CMB is in the circuitry of the LED driver. Using the experience with the CMBs and SiPMs at the HCAL, we found a value of the fixed pulse-width of 6 ns as an optimum. The new system employs a LED driver with a low level of noise and parasitic high frequency spectrum. It is called the Quasi-resonant LED Driver - QRLED. The principal circuit diagram is on the Fig. 2.

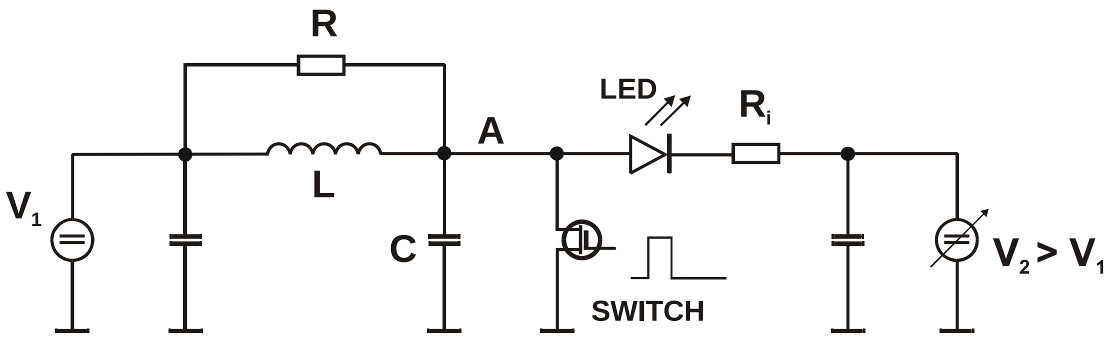

Fig. 2 - The principal circuit diagram of the Quasi-resonant LED Driver

The whole circuit is connected between two DC voltages. V_1 is constant, V_2 is variable, but always higher as V_1. The main components generating the electric pulse, are inductor L, capacitor C and a switch (in our case MOSFET). The switch is open between pulses. When switched on, the current begins to flow throw the inductor until the switch is off. The energy stored in the inductor is now transferred into capacitor C and the voltage across the capacitor (point A) is rising up very fast. The slope of the rise is defined by the value of the serial resonant circuit LC and is around 6 ns. When all charge from the inductor is transferred, the rise of the voltage stops and now the discharging of the capacitor begins. If the LED is connected to the point A, the discharging current flows throw it and the LED starts to shine and the voltage at the point A falls down. Because the cathode of LED is connected via resistor R_i to the variable voltage V_2, LED lights only if the voltage in the point A is higher than V_2. By setting the voltage V_2 it is possible to change the amplitude of the output pulse. The current flow throw the LED is seen as a voltage drop across the resistor R_i, 1 Ω in our case (see Fig. 3). As seen from the Fig. 3, at the end of the electric pulse an oscillation starts. It uses the remaining charge on the capacitor after the LED is reversed polarized and the current flow is blocked. These oscillations can create more than one output pulses in each period. To suppress this unwanted effect, a dumping resistor R is connected parallel to the inductor. With the optimal value of the resistor it is possible to keep the oscillations below the opening voltage of the LED and the optical LED output pulse is only the one in each period.

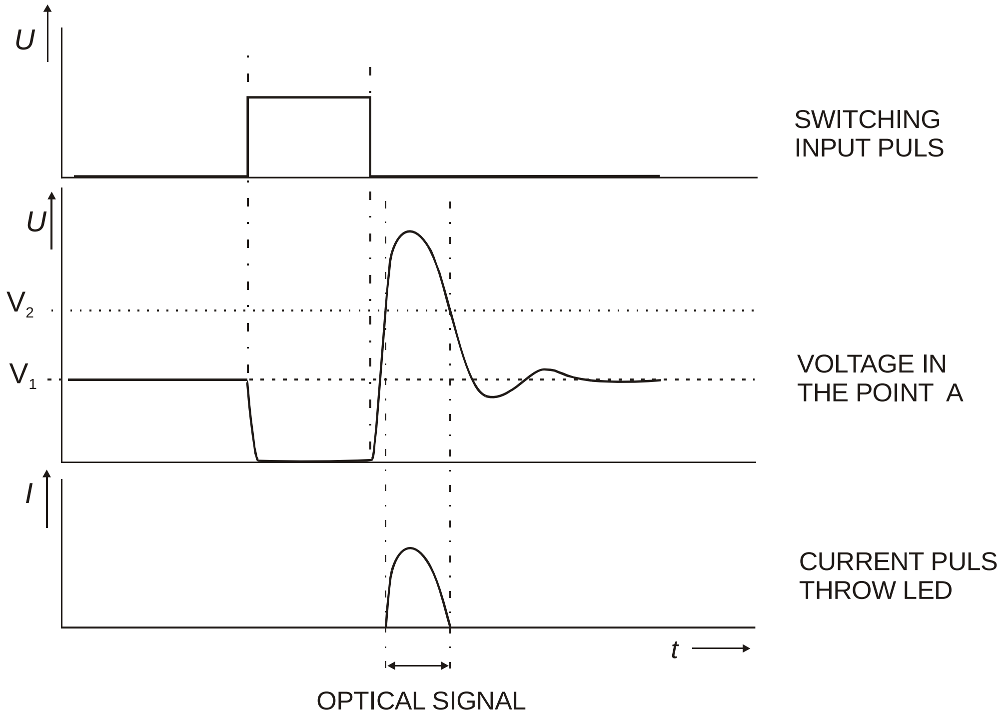

Fig.3 - Shape of the pulses on the circuit from Fig. 2

The intensity of the optical pulse is proportional to the amplitude of the electric pulse and the width is the same as the width of the electric impulse. It means, that the pulse width changes with the amplitude but the peak position remains the same (this is important for our application). In case, that the pulse should be constant, the voltage V_2 is kept on the lower value and the amplitude can be changed with the length of the switching pulse. By this way we can change the energy stored in the inductor. But it leads to a more complicated control of the electronic circuits.

1.3 Practical realization

We have realized a functional sample of two channels of the QRLED on a PCB and made first tests with it. This sample is built on a two layer PCB and uses for most of components the SMD technology. With help of an external generator we set values of critical components. At the PCB we can find 2 channel LED system, 2 PIN photodiodes preamplifiers with 50 Ω line-driver, rate generator with several outputs signals from 1 Hz to 10 kHz . We placed on board our HCAL V-calib and T-calib interface, which can be used instead of a manual control (see Fig. 4).

Original target is to generate pulse 6 ns wide. On this PCB we use printed inductors, and due to a certain coupling to the ground, the final pulse width measured is 2 ns value using a differential 1 GHz probe and 1 GHz oscilloscope TDS4104. To reach the pulse width value of 6 ns, the inductor has to have a larger inductance around 50 nH. This can be done by placing a discrete (not printed) inductance on the board.

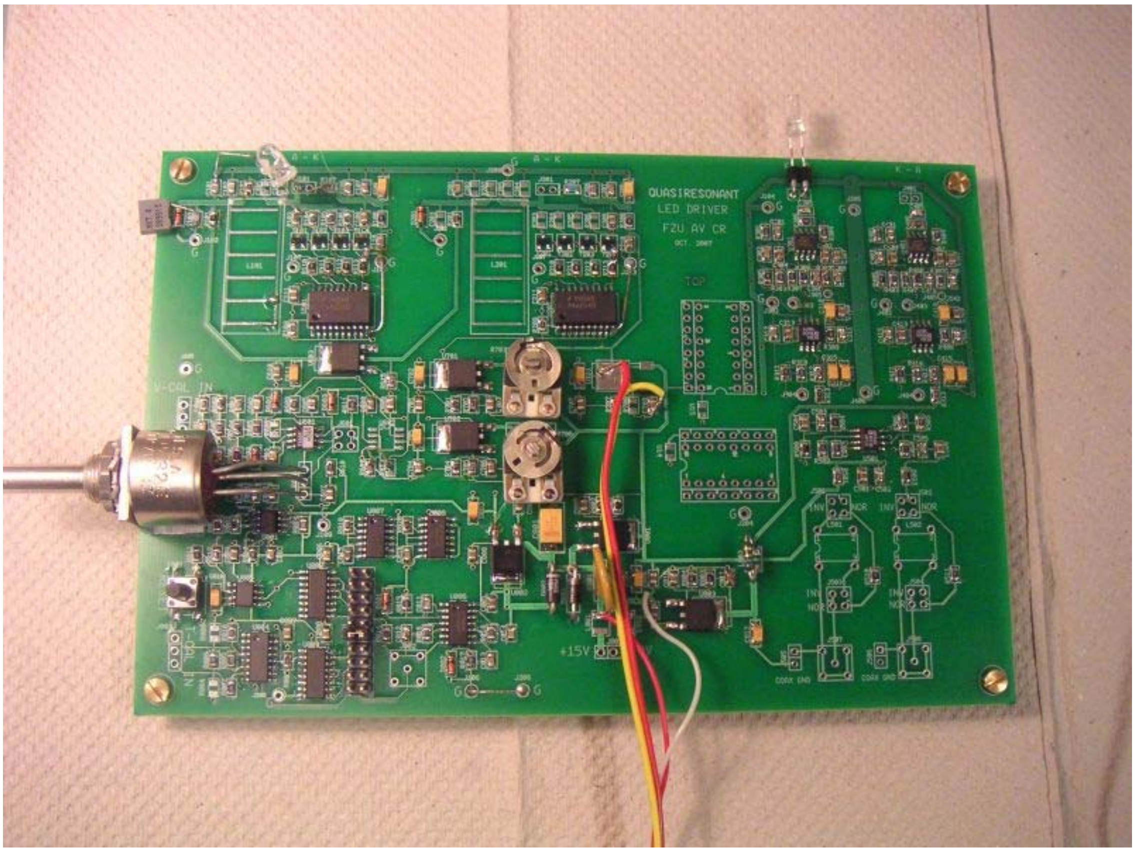

Fig. 4. View of the QRLED on a PCB during the test measurement.

In Figs. 5-7 from an oscilloscope, the yellow trace shows a current flowing through the resistor R_i. Each figure shows a different current, which is primer to the output amplitude. It was measured with a voltage 1 GHz differential probe on the 1 Ω smd 0805 resistor. We can interpret these oscillograms as a current 1 A corresponding to 1 V per division. Forward LED current is positive, over baseline, marked 1 at the left side. The horizontal scale is 4 ns/div and the vertical 500 mV/div (= 500 mA).

As LED has a certain parallel parasitic capacitance, a current passing through is split between this capacitance and active electrical to optical conversion process in chip. This can be seen at the oscillogram. Conforming test will be done with a fast photodetector (PM, SiPM). In Figs. 5 and 6 we see that the second peak of the oscillation is at the negative voltage and does not produce light at the LED. At the highest amplitude (Fig. 7) the second peak of the oscillation can produce the LED double pulsing. The suppression of this behaviour will require an additional adjustment of components in the LED driver.

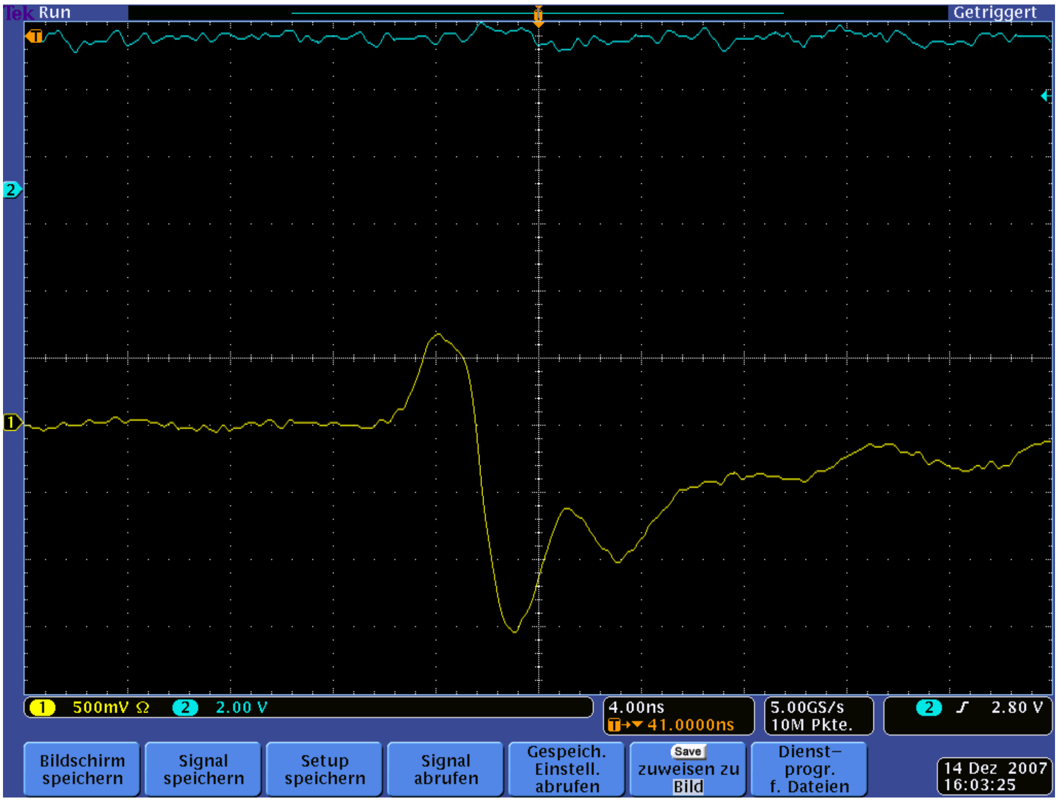

Fig.5. View of the LED pulse for a small amplitude (0.6 A)

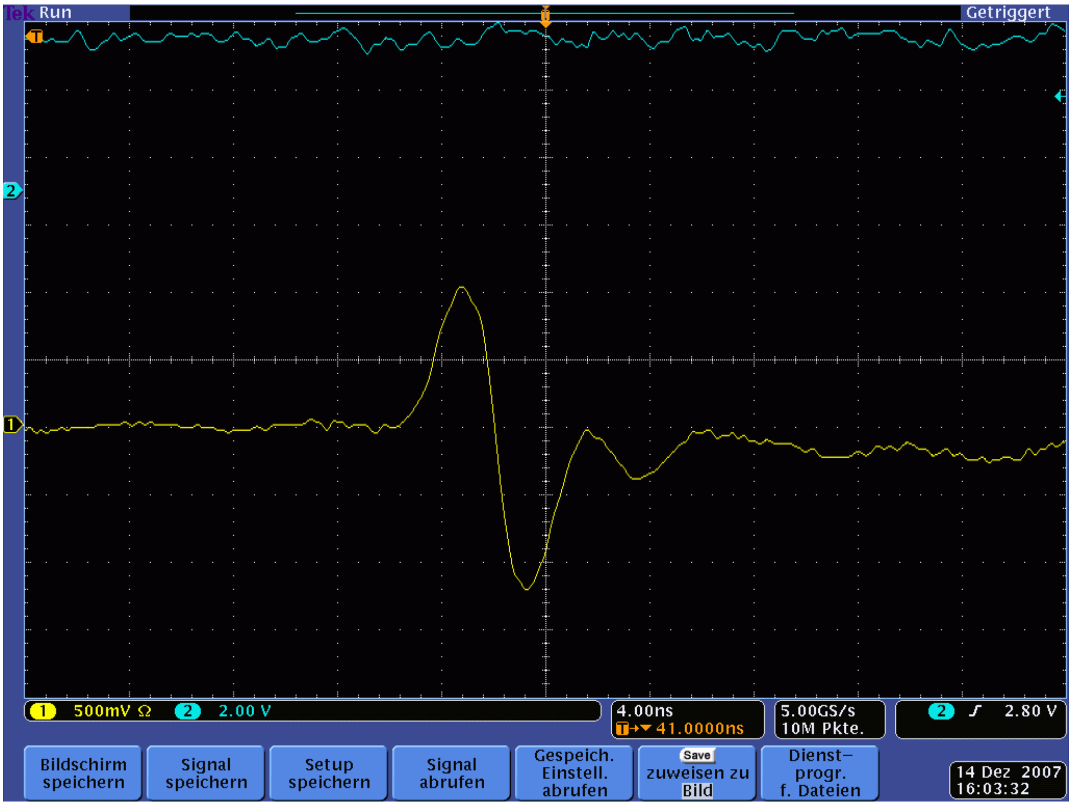

Fig.6. View of the LED pulse for a middle amplitude (1.0 A)

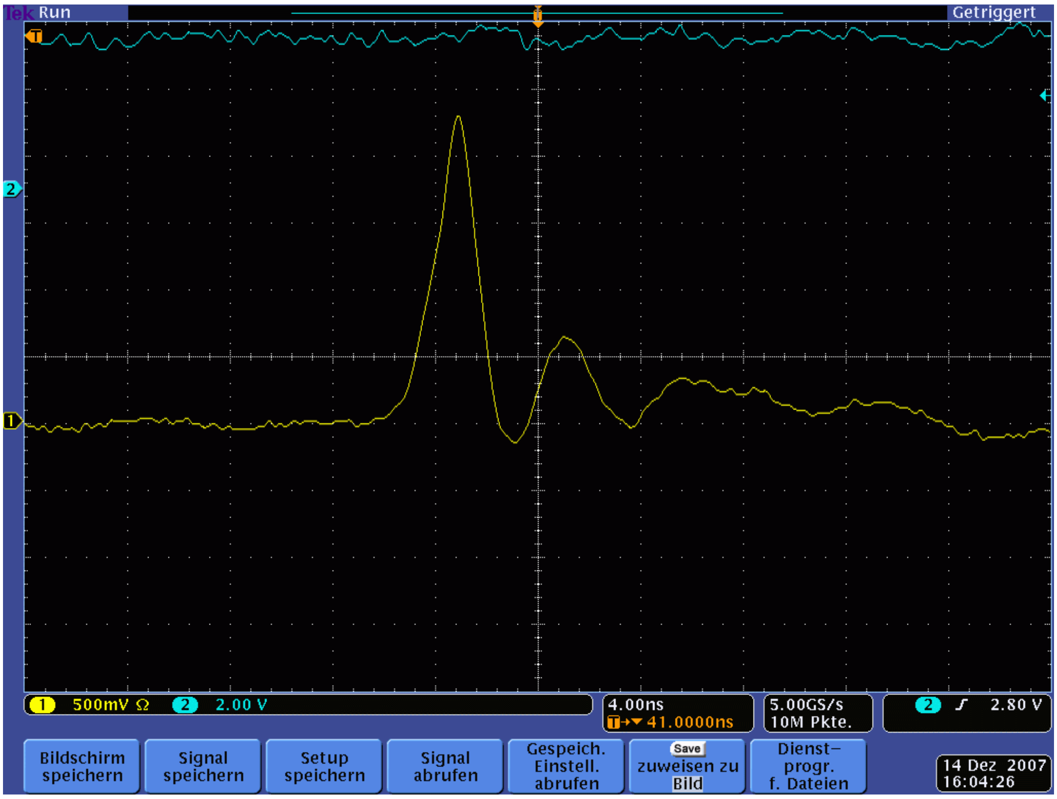

Fig. 7. View of the LED current pulse for the highest amplitude (2.3 A)

3 Conclusion

The Quasi Resonant LED system was built and tested. Two channel system includes 2 LED drivers, 2 PIN photo-diode preamplifiers, rate generator and interface to AHCAL electronics. The system allows to set the current flow through an LED up to 2.3 A and exceeds the operational range which we had in the calibration system of the HCAL physics prototype. This PCB realisation shows narrower (faster) LED signal (2 ns) than simulation and tests with a simplified one channel prototype (6 ns). The 2-channel prototype will be used for further experimentation with additional external inductors to find the optimal value of the LED pulse. In the next step we will also study the use of the air-core toroidal inductor, to suppress unwanted magnetic coupling.

By this memo we confirm the accomplishment of the JRA3 milestone: “HCAL calibration single channel prototype available”.

Acknowledgement

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