Application Note - LTC-1141 in Integrated Cavity Output Spectroscopy

Application note written in highly appreciated collaboration with
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1 Abstract

In this application note, we describe the use of the Meerstetter Engineering LTC-1141 controller in the OA-ICOS (= Off Axis Integrated Cavity Output Spectroscopy) instrument AMICA (= Airborne Mid Infrared Cavity enhanced Absorption spectrometer) for operation and control of mid infrared laser diodes and for data acquisition.

2 Device Overview

The LTC controllers are laser diode drivers with an integrated TEC controller (based on the TEC-1091).

The core of the LTC controllers consists of a system-on-chip featuring high performance processing capabilities in combination with fast ADC, DAC and memory. This allows fast modulation, sampling as well as onboard data processing.

Object (laser diode, sensor, etc.) cooling is managed by the onboard TEC controller featuring high temperature stability and high measurement precision.

Product Highlights:
Low noise laser diode current
High bandwidth (up to 0.5 MHz)
High efficiency TEC controller (DC output)
Very high temperature stability (0.005 °C)
Auto tuning for PID values of TEC controller
Fast 16-bit A/D and D/A conversion
Integrated signal processing

Main Features:
Laser Diode Driver (LDD):
- 0.5 MHz modulation bandwidth
- Integrated signal generator
TEC/Peltier controller (TEC):
- Fast and high precision temperature control
LDD and TEC integrated on one board
LDD and TEC fully digitally controlled

Applications:
Spectroscopy
Radar
Medical diagnostics
Chemical analysis
General measurement systems

Application data processing:
- 11 configurable digital or 5 analog IOs (X3)
- 1 fast analog input (differential) reserved for sampling and measurements (X2)
- 1 fast analog output (X4)
- Custom current waveforms
- Synchronous sampling and measuring
- Capacity for data processing, sampling, measurement sequences and oscilloscope functionality

Please refer to the User Manual and the Data Sheet for details.

3 Application

3.1 Measurement principle and overview of the AMICA instrument

Figure 1 Photograph of AMICA installed inside the cabin of the German research aircraft HALO

AMICA (shown in Figure 1) has been developed at Forschungszentrum Jülich GmbH, Institute for Energy and Climate Research – Stratosphere (IEK-7; https://www.fz-juelich.de/iek/iek-7/EN/Home) together with ABB-Los Gatos (www.lgrinc.com) for airborne trace gas measurements using OA-ICOS (Bear et al., 2002; see Figure 2 for an illustration) in two separate cavities. Infrared spectra are recorded in two spectral windows (one with each cavity, typically a few cm^{-1} each) defined by suitable combinations of laser, mirrors and detector. Lasers used in the mid-IR include quantum cascade lasers (QCLs) and Interband Cascade Lasers (ICLs), and photodiodes are normally used as detectors in AMICA. High mirror reflectivity in the chosen wavenumber range is implemented by a dielectric coating on the mirror side facing into the cavity. Depending on the spectral windows selected, multiple trace gases can be measured simultaneously. In AMICA, the OA-ICOS cavities and related hardware are housed in a temperature controlled (35 ± 1 °C) enclosure. The instrument is designed to fulfil all the mechanical and electronic requirements for use on research aircraft. Full details on the design, characteristics and operations are described by Kloss et al. (2021).

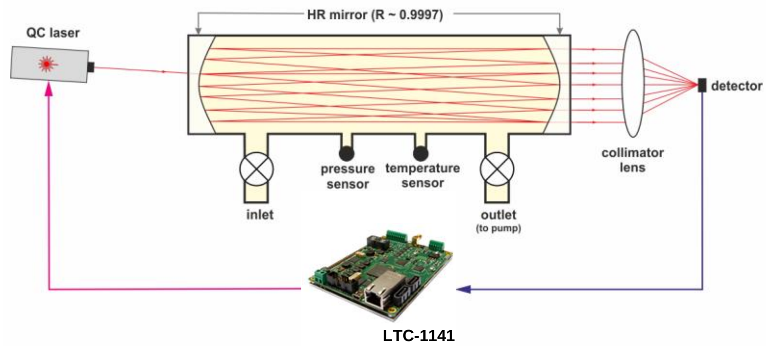

Figure 2 Illustration of OA-ICOS. In AMICA, both laser diode control and detector signal acquisition and processing is done by the LTC-1141 as described below.

3.2 Laser Control and Modulation

In a typical OA-ICOS application, a laser diode is operated at a constant temperature and its current is repetitively ramped to scan over a desired range of typically a few wavenumbers. At the end of each ramp, the laser current is turned off or reduced below the lasing threshold so that the decay or *ring down* of light in the cavity and the dark signal at the detector can be monitored. The resulting laser current modulation is shown in Figure 3. One ramp period is typically on the order of a few milliseconds.

Meerstetter Engineering LTC-1141 controllers are used for temperature control and current modulation of the laser diodes in AMICA (currently, four cavity configurations with three Hamamatsu QCLs and one Nanoplus ICL are possible). In combination with TEC control of an insulated housing surrounding the laser mount (using a Meerstetter TEC-1122 controller), the TEC control of our laser diodes by the LTC-1141 attains temperature stabilities better than ± 0.005 K. The laser modulation (described above and shown in Figure 3) is defined in a lookup table containing a series of laser current values for one ramp period that is uploaded to the LTC-1141 and then scanned at the selected rate.

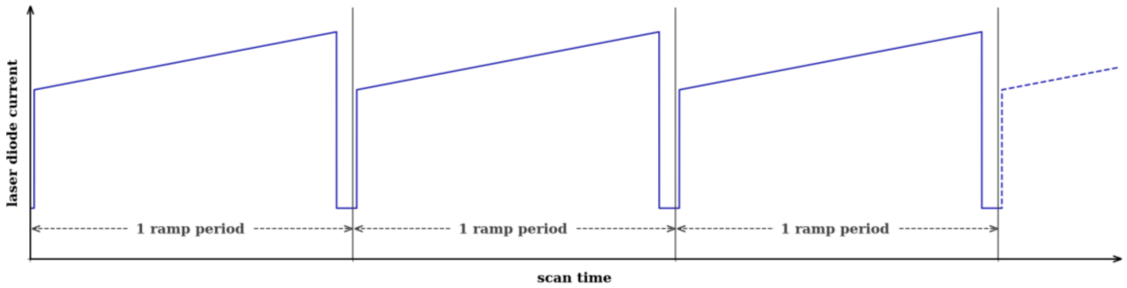

Figure 3 Laser current modulation as typically applied in OA-ICOS.

3.3 Use of the LTC-1141 for data acquisition

Light exiting the cavity is collimated onto the detector (see Figure 2), inducing a current proportional to the light intensity. The current signal is amplified and converted to voltage by a preamplifier (Femto). The voltage signal from the preamplifier is then passed on to the fast analog input AD channel of the LTC-1141 controlling the cavity laser.

The digitized signal is averaged by the LTC-1141 on-board microprocessor over a selected number of ramp periods, with the number of points per ramp period matching the number of values given in the laser current lookup table. Together with a set of basic parameters (TEC object and sink temperatures, LTC-1141 board and CPU temperatures, LTC-1141 input voltage) the averaged ramp is transferred to an embedded PC/104 stack via UDP data stream.

3.4 Custom Firmware for the LTC-1141

Initial evaluation of the device was made using the standard firmware. The standard firmware allowed to collect sample measurement data to verify the system.

As the needs for the final application could not be covered with the device as it was, the user then contracted Meerstetter Engineering to develop a customization, providing a list of requirements and acceptance criteria.

In particular, it was not possible to transfer every single ramp to the master device, due to the quantity of data involved. Additionally, this was not optimal as the ramps would then get averaged anyway. It was decided to move the averaging to the LTC-1141 in order to offload the computational load and eliminate the need for transfering massive amounts of data, and change the way the ramps are sent over to the master device in order to allow a continuous transfer of all the data that is generated, without loss of continuity.

Meerstetter Engineering subsequently implemented a data collection and elaboration function that allows to collect data for all the measured ramps, average them and then send them via a UDP data stream.

As both the current ramp generation and the measurement are handled by the same device, the measurement and the current generation are synchronized, as they get triggered in the same clock cycle.

The custom firmware allows to pick the following parameters:

Parameter	**Range**
# of points in the lookup table	1000 – 5000
LUT sampling rate [s]	1E-7 – 1E-5
# of samples per measured ramp	1000 – 5000
# of consecutive 10 ns samples to average	10 – 1000
# of ramps to average	50 – 2000

This allows the user to freely choose how many look-up table executions to sample or how fast the look-up tables were to be, within the limits of the sampling clock, the look-up table depth and the communication speed.

The result is a continuous data stream of measured and averaged ramps, that is then handled by the user's master device. An UDP listener program was provided for verification purposes.

The customer decided to make this customized LTC-1141 firmware available for further use, please contact Meerstetter Engineering for more information.

3.5 References

Bear, D.S., Paul, J.B., Gupta, J.B., and O'Keefe, A.: Sensitive absorption measurements in the near-infrared region using off-axis integrated-cavity-output spectroscopy. Appl. Phys. B 75(2-3), *261-265*, 2002.

Kloss, C., Tan, V., Leen, J.B., Madsen, G.L., Gardner, A., Du, X., Kulessa, T., Schillings, J., Schneider, H., Schrade, S., Qiu, C., and von Hobe, M.: Airborne Mid-Infrared Cavity enhanced Absorption spectrometer (AMICA). *Submitted to Atmos. Meas. Techn.*, 2021. (https://amt.copernicus.org/preprints/amt-2021-28/)

A Change History

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