Galvanically isolated interface for an oscilloscope

Martin Pospisilik, Petr Neumann, Roman Honig, and Peter Scheibenreiter

Abstract— The paper describes an approach to design and construction of a galvanically isolated interface for an oscilloscope. The device has been drawn in two samples showing how helpful the galvanic isolation of the oscilloscope can be at certain service operations. The monitored signals are transferred by means of a capacitive coupling through an isolation barrier inside a custom integrated circuit, described hereby as well.

Keywords—Differential Measurement, Oscilloscope, Isolating Amplifier, Galvanic Isolation

I. Introduction

MOST oscilloscopes use single ended input [2] the negative pole of which is usually grounded to a common ground. This construction allows the operator to measure only those waveforms that are referenced to the ground. If there is a need for differential measurements, two inputs must be involved and the oscilloscope must be switched into a differential measurement mode. Although this practice is satisfactory in most cases, it brings several disadvantages as enlisted below:

- Measurement of one waveform employs two oscilloscope's channels,
- Errors in measurement are cumulated from both channels,
- Common mode rejection ratio is considerably low, especially when the differential voltage is quite low compared to the potential of the measurement points relative to the ground.

As it turned out during service measurements, the differential input is often needed. Therefore the authors decided to construct the proper interface that is described within the framework of this paper.

II. Requirements and Prerequisities

The initial requirements were as follows:

- Two different channels for voltage and current measurements,
- Possibility of the zero level correction,
- Measured voltage range ± 20 V,
- Measured current range ± 1 A,
- Isolation strength between input and output at least 1.5 kV,
- Frequency range DC to 30 kHz.

On the basis of the above mentioned requirements it was decided to apply the isolation amplifier ISO124 [3] and to equip it with additional output low pass filter. The construction of the differential inputs and the output low pass filters is based on JFET operating amplifiers TL081 [4].

A. *Isolating amplifier ISO 124*

The ISO124 is a precision isolation amplifier incorporating a duty cycle modulation-demodulation technique. The signal is transmitted digitally across a 2pF differential capacitive barrier. With digital modulation the barrier characteristics do not affect signal integrity, resulting in excellent reliability and good high frequency transient immunity across the barrier. Both barrier capacitors are imbedded in the plastic body of the package. No external components are required for operation. The key specifications are 0.010 % max nonlinearity, 50 kHz signal bandwidth, and 200 μV/°C V_{OS} drift. A power supply can lie in the range of ±4.5 V to ±18 V [3].

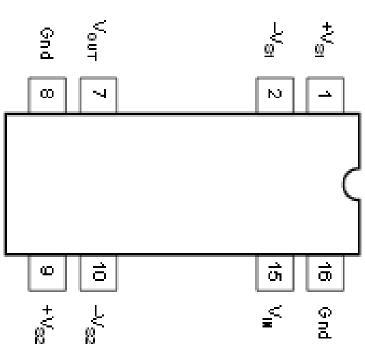

Fig. 1 DIP package connection diagram of ISO124 (top view) [3]

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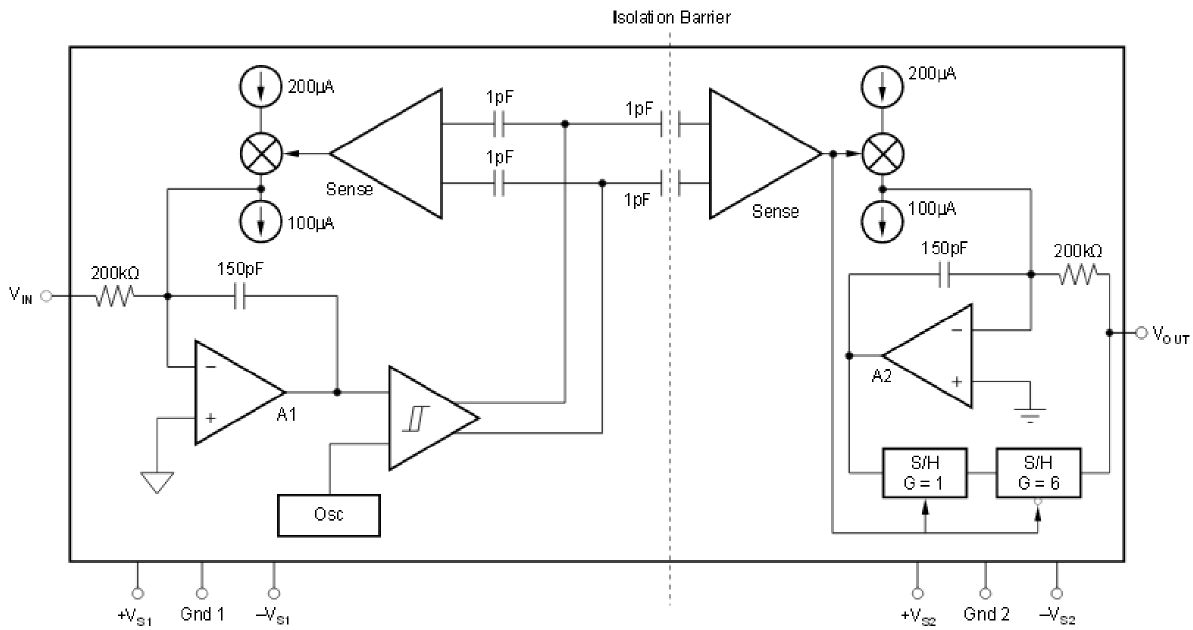

Fig. 2 Block diagram of internal circuits in ISO124 [3]

The package of the device is adjusted to allow achieving the continuous isolation voltage of 1,500 V_{RMS}. Therefore the amplifier is encapsulated in 16-pin plastic DIP or 28-lead plastic SOIC package. The connection of pins is described in Fig. 1.

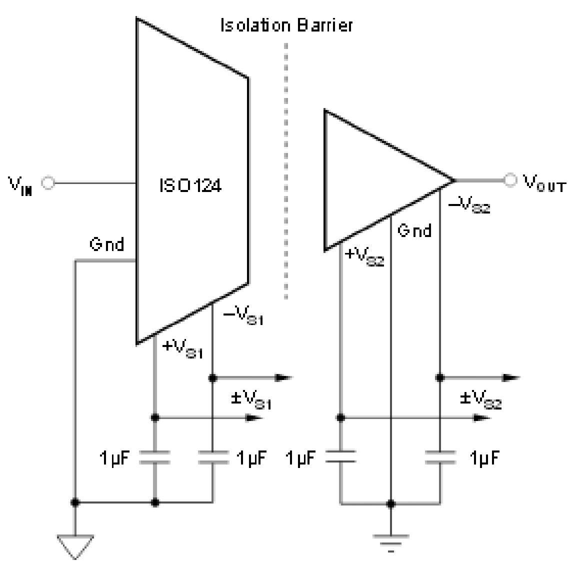

Fig. 3 Basic signal and power connections of ISO124 [3]

In Fig. 2 the block diagram of internal circuits in ISO124 can be found. The input amplifier A1 integrates the difference between the input current and the switched ± 100 μA current source. The internal oscillator forces the current source to switch at the frequency of 500 kHz. The complete block at the front-end of the isolation barrier creates a modulator that produces triangular wave at the frequency forced by the internal oscillator and the duty cycle proportional to the voltage at the input pin V_{IN}. At the back-end of the isolation barrier there is a sense amplifier that detects the signal transitions across the barrier and drives a switched current source into the integrator A2. The output stage balances the duty-cycle modulated current against the feedback current through the 200 kΩ feedback resistor, resulting in an average value at the V_{OUT} pin. [3]. As a result of the operation, 20mV ripple at the frequency of 500 kHz is present at the output of the circuit. This can be removed by additional low pass filter. The basic signal and power connections of the amplifier are depicted in Fig. 3.

In figures 4 to 7 the typical performance of the amplifier according to its datasheet [3] is depicted.

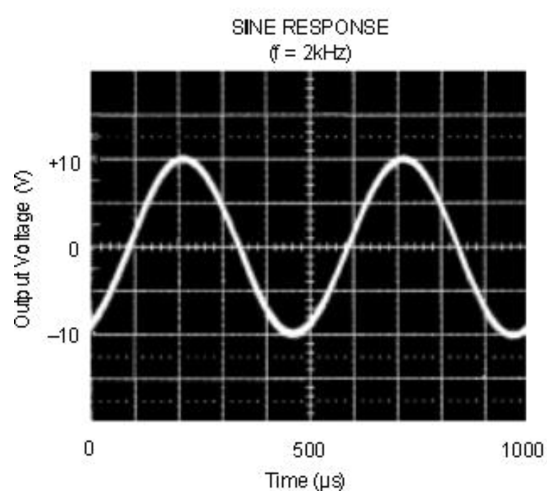

Fig. 4 Sine response of ISO124 on the signal with f = 2 kHz and V_{PP} = 20 V [3]

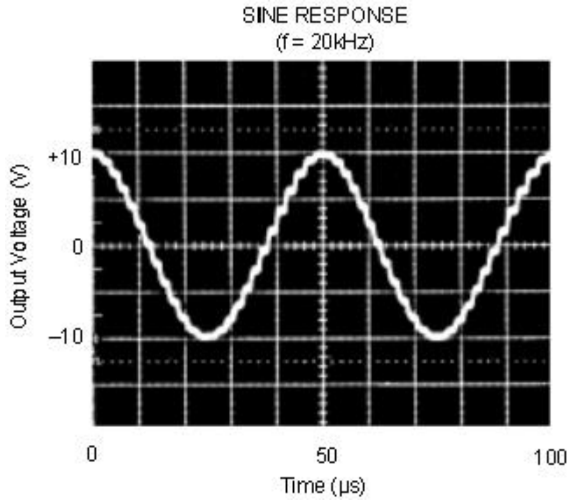

Fig. 5 Sine response of ISO124 on the signal with f = 20 kHz and V_{PP} = 20 V [3]. The effect of sampling can be observed here.

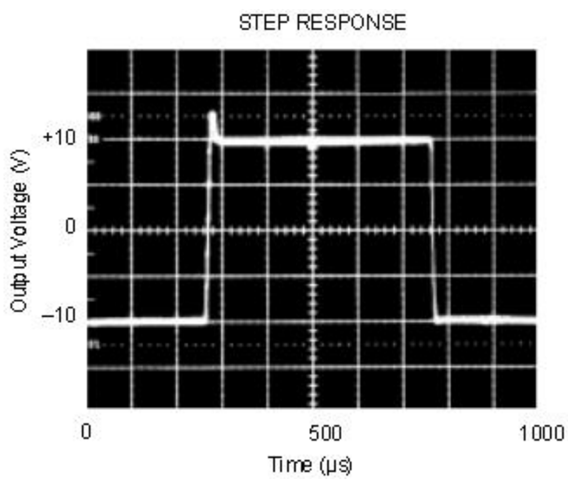

Fig. 6 Step response of ISO124 to a pulse wide 500 μs [3]

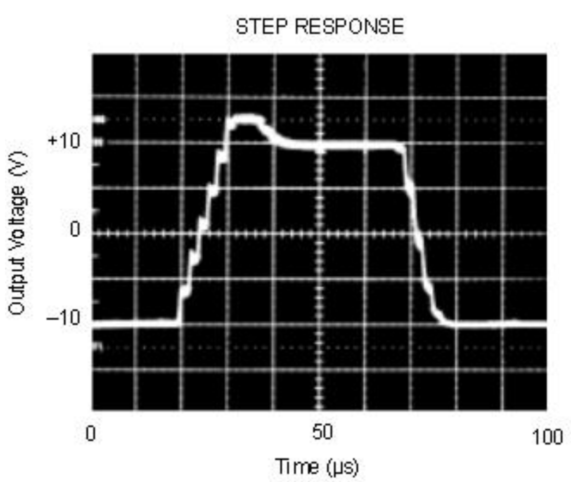

Fig. 7 Step response of ISO124 to a pulse wide 50 μs [3]

B. *Operating amplifier TL081*

The TL081 is a low cost high speed JFET input operational amplifier with an internally trimmed input offset voltage. The device maintains a large gain bandwidth product and fast slew rate. The noise and offset voltage drift is also at low levels. The absolute voltage offset can be set by an external trimmer. According to [4], the parameters of the device are as described in Table I.

Table I Parameters of TL081 [4]

Parameter	Value
Input bias current	50 pA
Input noise voltage	25 nV/$\sqrt{\text{Hz}}$
Gain bandwidth	4 MHz
Slew rate	13 V / µs
Supply current	1.8 mA
Input impedance	10^{12} Ω

The typical connection of TL081 including the zero level correction is depicted in Fig. 8. The internal connection of the amplifier is depicted in Fig. 9.

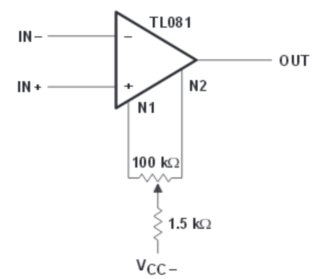

Fig. 8 Basic connection diagram including zero level setting [4]

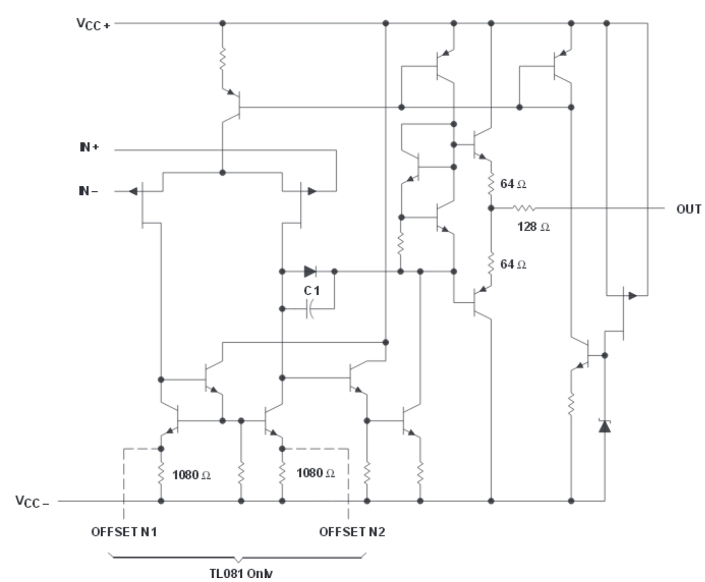

Fig. 9 Internal connection of TL081 [4]

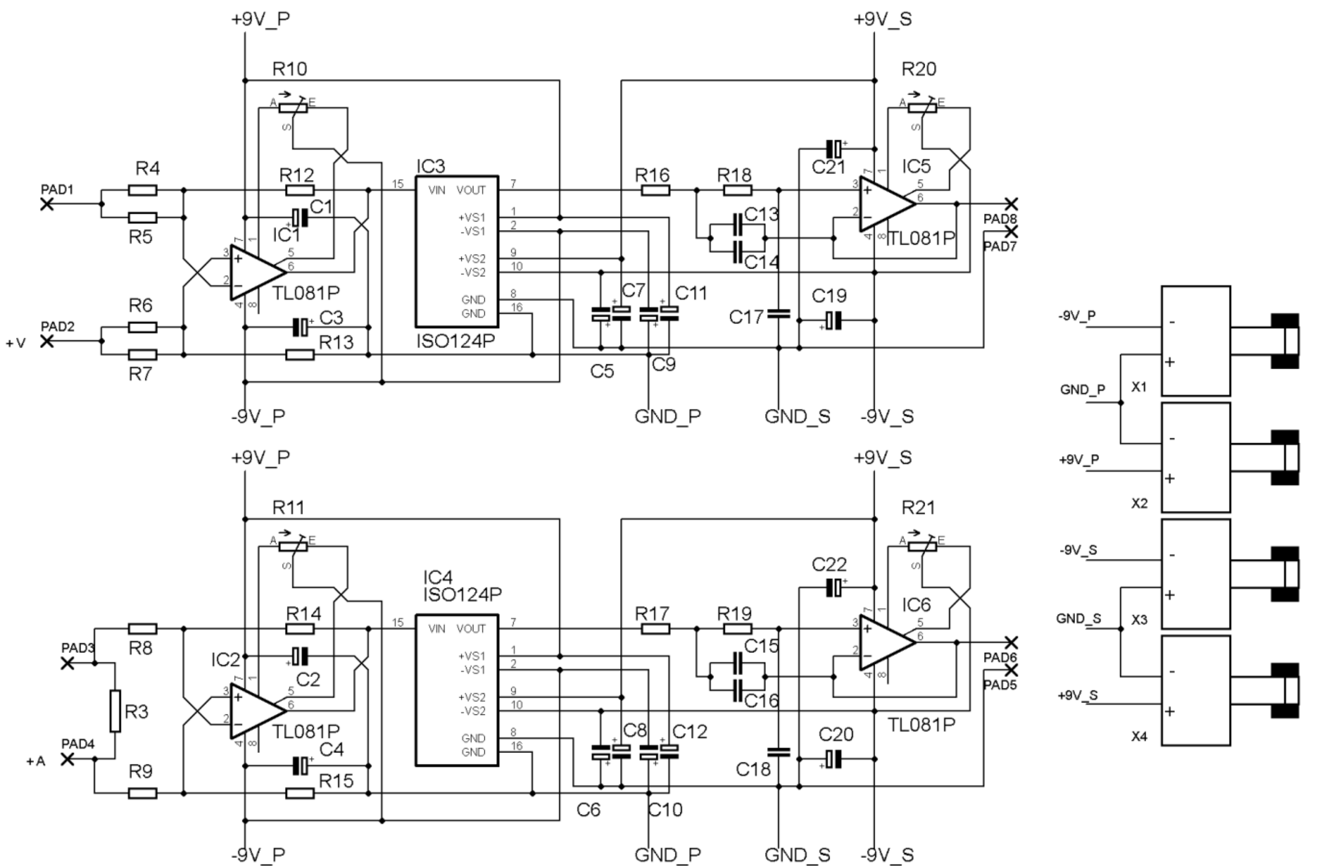

Fig. 10 Isolating interface circuit diagram

III. The Construction

The dual channel isolating amplifier was constructed in two versions. One of them require an external power source while the second one, the circuit diagram of which is depicted in Fig. 10, employs four independent 9 V batteries. This solution is more convenient for using the device at servicing outside the laboratory.

The device is constructed on a single double sided printed circuit board, including the battery holders. The inputs and outputs of the channels are equipped with pins to which the cables with crocodile clips can be attached. In the neighborhood of each of the operating amplifiers there are precise trimming resistors allowing accurate zero level setting. The printed circuit board is strictly divided into primary and secondary part. These parts are coupled only by means of the ISO124 isolating amplifiers.

Four 9V batteries are mounted in appropriate holders X1 to X4. The power supply nets are different for the "primary" (frontend of ISO124) and the "secondary" (backend of ISO124) part. Also the grounds are strictly separated. The "primary" power supply nets are marked with the letter P (+9V_P, GND_P, -9V_P) while the "secondary" power supply nets are marked with the letter S (+9V_S, GND_S, -9V_S). All power supply inputs of the pertinent integrated circuits are blocked by tantalum capacitors as close to the appropriate pins as possible. The power paths on the printed circuit board were designed carefully in order to protect the output of the device from noise caused by switching of the circuitry inside the isolating amplifiers (see Fig. 2).

The input of the "voltage" channel is at pins PAD1 and PAD2. The sign "+" shows the polarity of the input. This sign is also depicted at the printed circuit board. The input of the "current" channel is at pins PAD3 and PAD4, also marked with the appropriate sign. The input stages are realized by means of operating amplifiers IC1 and IC2 in a conventional connection. The input resistance of the "voltage" channel is approximately 50 kΩ. The current is measured by means of the shunt resistor R3 the resistance of which is 0.1 Ω.

The output filters are based on the operating amplifiers IC5 and IC6. The values of the appropriate devices were set so the 2nd order Butterworth's transfer function was achieved. Consequently, smooth modification of the device values were made so higher Q was achieved close to the corner frequency. The corner frequency is tuned to approximately 35 kHz. The measured frequency response of the channels is depicted in Fig. 11.

The outputs of the relevant channels are connected at pads 5, 6, 7 and 8.

In Fig. 12 there is a photo of the battery-powered device. The device list is enlisted in Table II. Some of the positions are omitted for the battery-powered version that is described within the framework of this paper.

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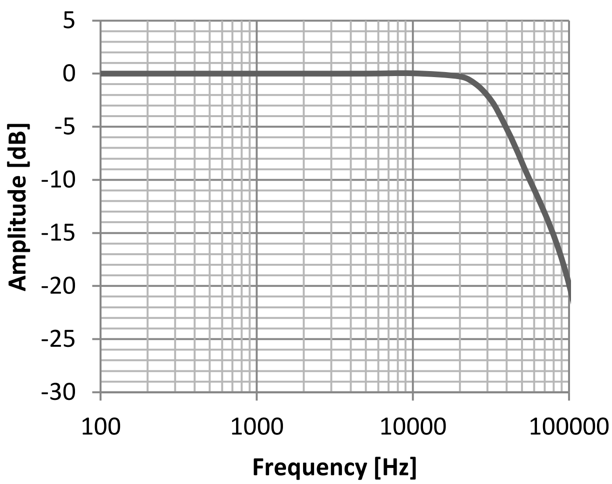

Fig. 11 Typical frequency response of the isolating interface

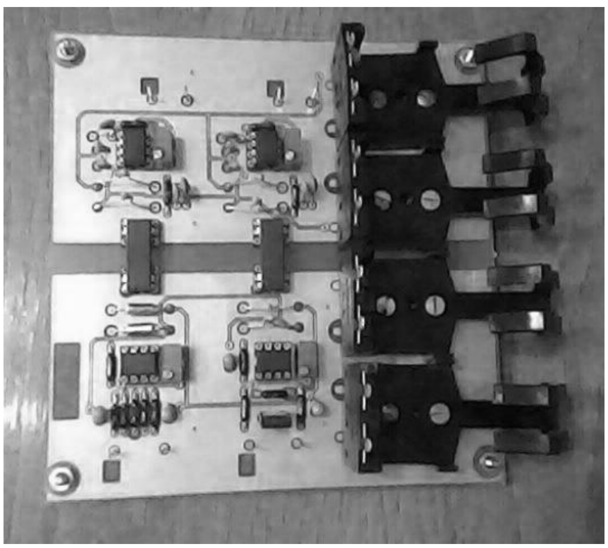

Fig. 12 Battery powered version of the isolating interface

Table II Device list

Position	Value	Note
R3	0.1 Ω	1 %, 1 W
R4, R5, R6, R7, R14, R15	100 kΩ	1 %
R8, R9	1 kΩ	1 %
R10, R11, R20, R21	100 kΩ	Multiturn trimmer
R12, R13, R16, R17, R18, R19	10 kΩ	1 %
C1 to C12, C19 to C22	1 - 10 μF	tantal
C13, C15	68 pF	ceramic
C14, C15	680 pF	ceramic
C17, C18	330 pF	ceramic
IC1, IC2, IC5, IC6	TL081	See [4]
IC3, IC4	ISO124	See [3]
X1 to X4	9V battery holders	

IV. Conclusion

This paper provides a description on a construction of a dual channel galvanically isolated interface for an oscilloscope that enables measurement of differential voltages or currents of those waveforms the bandwidth of whose does not exceed approximately 30 kHz. The device utilizes the isolating amplifier ISO124 with discrete-time modulation.

The device has been built in two versions. One of them requires external power supply while the second one is powered from batteries mounted directly on the device. This version is successfully used at service operations outside the laboratory.

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