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Optically-isolated input modules for a 0-5V or 4-20mA to 0-5V signal converter

By Professor Murat Uzam, Department of Electrical and Electronics Engineering, Yozgat Bozok University, Turkey

In this month's column we will cover two optically-isolated analogue input modules for a 0-5V or 4-20mA to 0-5V signal converter. Module 1 (Figure 1) handles DC input voltages from 0V to +12V, or DC input currents from 0mA to 48mA, and requires DC power supplies of +6.26V, +12V and isolated +12V. Module 2 handles the same input voltages and currents but requires DC power supplies of +12V and isolated +12V.

Figure 2 shows Module 1's connections to an analogue input of a 5V microcontroller. This circuit contains the Positive Unipolar Photovoltaic Isolation Amplifier 1 (PUPIA1 – explained previously), with HCNR201 high-linearity analogue optocoupler for photovoltaic isolation.

The circuit's output, to the right of the HCNR201, is isolated from V_{IN}, to the left. Here we assume that when the voltage mode is selected, V_{IN} is between 0 and 12V, and when the current mode is selected, I_{IN} is between 0 and 48mA.

In voltage mode (S1 open), when $0.00V \leq V_{IN} \leq 5.00V$, $V_{OUT} = V_{IN}$. When $5.01V \leq V_{IN} \leq 12V$, V_{OUT} will be a value from 5.01V to 5.07V, due to the electrical characteristics of the LM358P-1A.

In current mode (S1 closed), when $0mA \leq I_{IN} \leq 20mA$, $V_{OUT} = (I_{IN} . 250)V$. When $20mA < I_{IN} \leq 48mA$, V_{OUT} will be a value from 5.01V to 5.07V, again because of the LM358P-1A.

The curves V_{OUT} vs V_{IN} and I_{IN} are shown in Figure 3; it can be seen that for input voltages to 12V and input currents to 48mA the circuit suffers no damage.

V_{IN} and I_{IN} can be subjected to electric surge or electrostatic discharge on the circuit's external terminal connections, but the TVS (transient voltage suppressor) provides highly-effective protection. D1 protects the circuit from accidental reverse polarity of V_{IN} or I_{IN}.

Jumper S1 (shown here as a switch) switches between current and voltage, with R1 = 250Ω used to adjust the levels. When S1 is open, the input can be 0-5V; when closed, the input can be 0-20mA.

A ferrite bead in series with the input path adds isolation and decoupling from high-frequency transient noises, whereas external Schottky diodes protect the op-amp. Even with internal ESD protection diodes, it's recommended to use external diodes since they lower noise and offset errors in the circuit.

Dual series Schottky barrier diodes D2 and D3 divert overcurrents to ground or the power supply. With its +6.26V power, the LM358P-1A op-amp acts as a voltage limiter, provides a high input impedance and is connected as a buffer amplifier (voltage follower). Its output is connected to the PUPIA1's input, limiting the input voltage.

Here, PUPIA1 consists of:

1. Input section: R2, R3, C3, LM358P-2A.
2. HCNR201 high-linearity analogue optocoupler.
3. Output section: P1, R4, C4, LM358P-3A.

In this design, the circuit's input section is powered by +6.26V and +12V; likewise, the output part is powered by another +12V power supply, isolated from the input. PUPIA1's output is connected to the non-inverting input of the buffer amplifier LM358P-3B. Output voltage V_{OUT} is thus obtained from the output of LM358P-3B.

Table 1 shows some example input and output voltages and currents for Modules 1

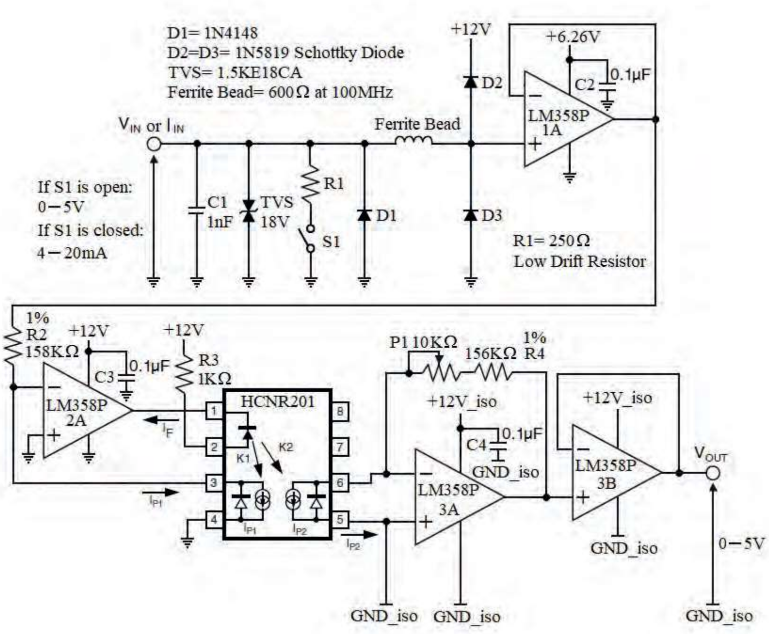

Figure 1: Module 1

and 2, with Figure 4 showing the PCB.

Circuit calibration is carried out with S1 open: set V_{IN} to +5.00V and V_{OUT} to +5.00V by adjusting P1.

Module 2

Figures 5, 6 and 7 show the optically-isolated analogue input module 2, with its connections to the ADC port of a 5V microcontroller. The circuit is also PUPIA1-based, with a high-linearity analogue optocoupler (HCNR201) providing photovoltaic isolation.

Module 2 operates exactly the same way as module 1, using the same components, but with R5, D4 (10V zener diode) and C5 added, which provide 10.00V reference voltage from a +12V power supply. The 10.00V reference is then divided with R6 and R7 to obtain +6.26V. This reference voltage is then connected to the non-inverting input of buffer amplifier LM358P-2B, with output fixed at +6.26V and sourcing to 20mA. For proper operation ensure that R7/(R6+R7) = 62.62%. EW

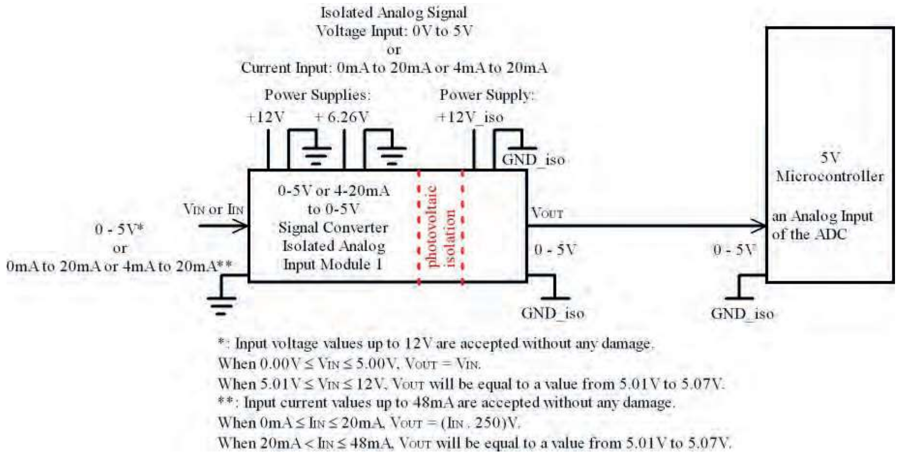

Figure 2: Module 1's connections to an MCU

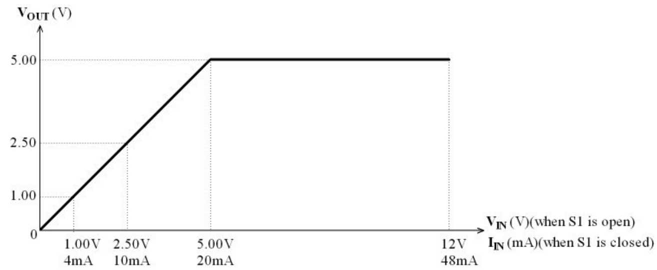

Figure 3: V_{OUT} vs. V_{IN} for modules 1 and 2

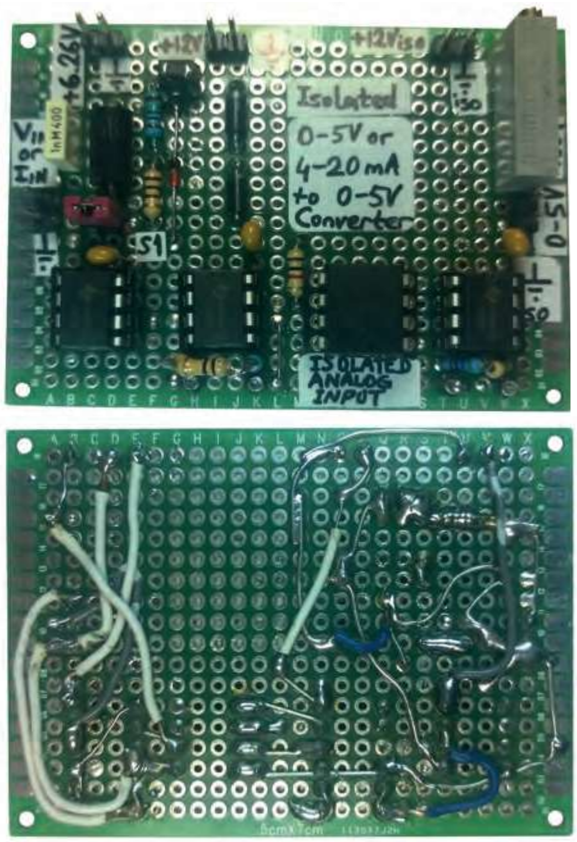

Figure 4: Module 1's PCB

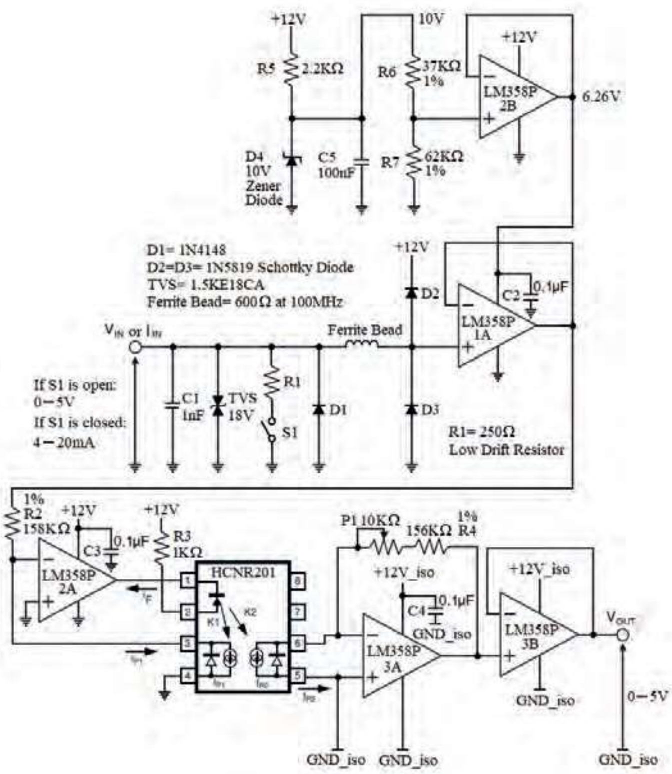

Figure 5: Module 2

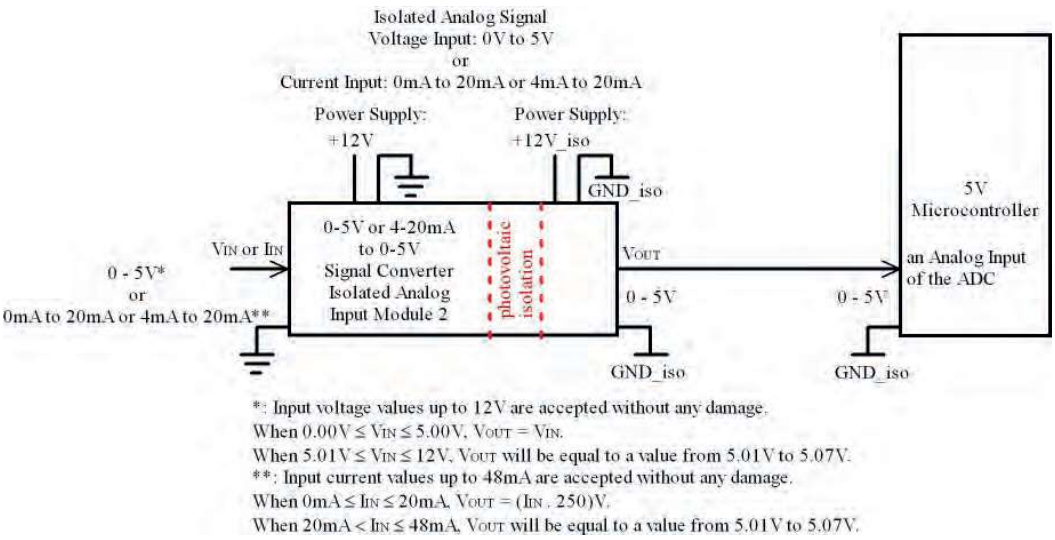

Figure 6: Module 2's connections

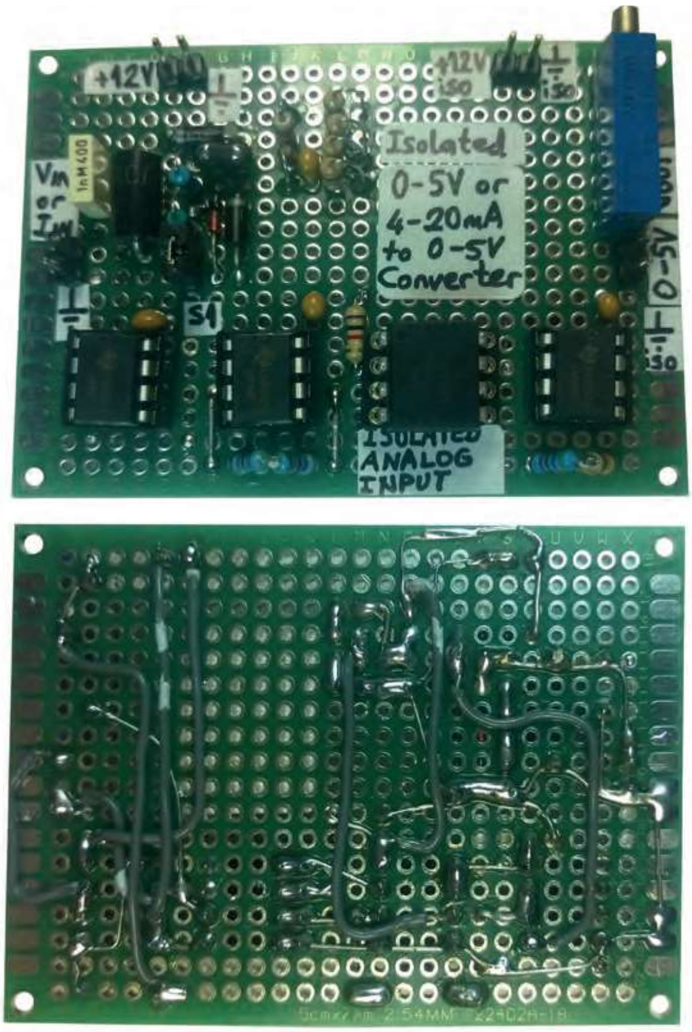

Figure 7: Module 2's PCB

V_{IN}(V)	I_{IN}(mA)	V_{OUT}(V)
12.00	48	5.0X
..	..	5.0X
10.00	40	5.0X
..	..	5.0X
5.00	20	5.00
..	..	..
4.75	19	4.75
..	..	..
4.50	18	4.50
..	..	..
4.25	17	4.25
..	..	..
4.00	16	4.00
..	..	..
3.75	15	3.75
..	..	..
3.50	14	3.50
..	..	..
3.25	13	3.25
..	..	..
3.00	12	3.00
..	..	..
2.75	11	2.75
..	..	..
2.50	10	2.50
..	..	..
2.25	9	2.25
..	..	..
2.00	8	2.00
..	..	..
1.50	6	1.50
..	..	..
1.25	5	1.25
..	..	..
1.00	4	1.00
..	..	..
0.75	3	0.75
..	..	..
0.50	2	0.50
..	..	..
0.25	1	0.25
..	..	..
0.00	0.00	0.00

Table 1: Example input and output voltages for Modules 1 and 2 (5.0X: a value from 5.01V to 5.07V)