

Ground-loop check

A simple experiment was devised to check out ground-loop effects. The sensing and drive circuitries were physically disconnected, and the driver was stimulated manually by direct connection to the driver power supply. Results (see Figure 146) proved beyond reasonable doubt that the non-linearity observed in polysilicon resistance measurements was due to ground-loop effects, and a serious redrawing of the underlying circuitry was undertaken.

PCR Cycles

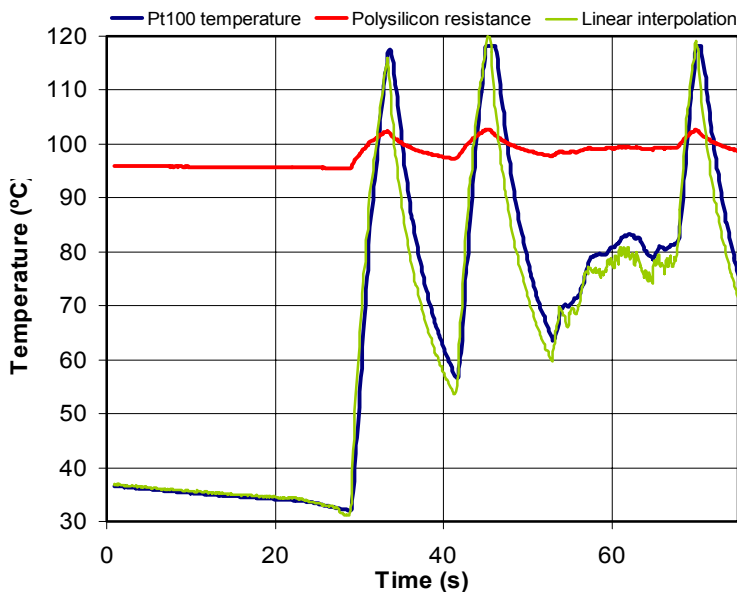


Figure 146 - Temperature sensing with physically isolated ground sources. Polysilicon sensor output becomes again manifestly linear (as demonstrated by the linear fit with Pt100 read temperature (green line)) and thus calls for discarding both infrared radiation and capacitive coupling hypotheses in favor of a simpler ground-loop explanation.

Circuitry reconfiguration

Although ground loops provide a far simpler account of sensor non-linearity than either infrared or capacitive coupling, this does not imply that circumventing them is a simple issue. In fact, dealing with ground loops is an extremely tricky design issue in power electronics and is often found to be at the core of many unapparent design dysfunctions. In this particular case, the elimination of ground loops required a careful redesign of the driver circuitry and, perhaps, of some parts of the sensing circuitry. Moreover, since ground-loop effects had not been observed during calibration and direct coupling factors had been already dismissed, the obvious conclusion was that the own heater resistor grid (a 5-6 Ω resistor)

was closing a relatively mild ground path, and circumventing this problem could ask for to very elaborate ground control mechanisms. Therefore, considering the foreseeable amount of time that such a circuitry redesign and adjustment would take, a more drastic alternative (photoelectric ground isolation) was taken for practical reasons, even though this solution was not extremely elegant in an electronic sense.

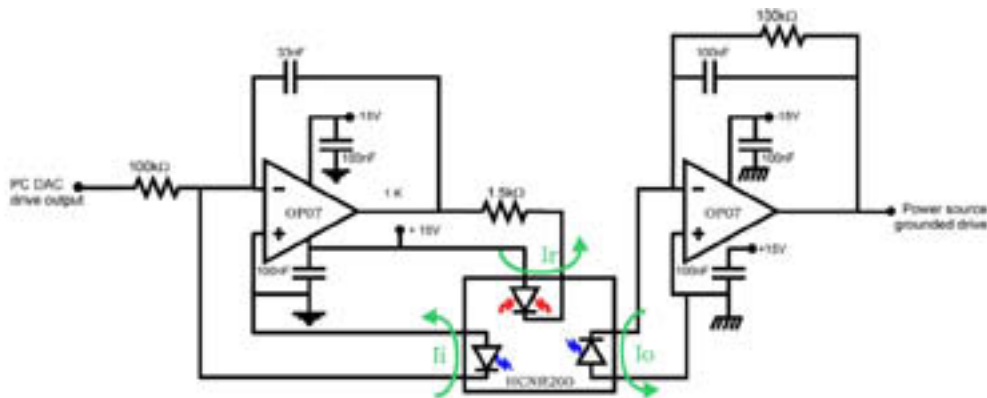


Figure 147 - Schematic circuit for photoelectric isolation of the PC-DAC drive output. Green lines represent the only possible current outputs. A similar circuit was developed for sensing of driver power consumption voltage outputs.

Effective photoelectric isolation between sensing and driving circuitries was accomplished by means of a HCNR200 high-linearity analog opto-coupler (*Agilent Technologies*). In contrast to conventional, digital opto-couplers, the HCNR200 exhibits two separate photodiode (instead of transistor-like) outputs. A light-emitting photodiode (LED) is placed in between, delivering approximately the same amount of light to both receiving photodiodes. An external OP07 amplifier (*Analog Devices*) monitors the LED output light through a negative feedback link using the first photodiode, and thus stabilizes the LED output, which is in turn regulated by the input voltage. The output photodiode then converts the stable, linear light output of the LED back into current, and a second OP07 amplifier reverts this current to voltage. Since op-amps tightly limit current flow, the following assumptions can be made on the circuit:

$$I_i = \frac{V_i}{100k\Omega}; \quad I_i = k \cdot I_o; \quad V_o = I_o \cdot 100k\Omega; \quad \Rightarrow \quad V_o = \frac{V_i}{k}$$

Equation 12 - Basic equations governing Figure 147 circuit. k is a linear gain constant provided by the opto-coupler manufacturer.

Therefore, by thoroughly adjusting both feedback resistors, a linear relation between input and output voltages can be attained. Additionally, the 1.5 kΩ load resistor is used to limit the maximum current that could flow through the LED (~15 mA) and thus avoid LED damage. After the incorporation of the opto-coupler isolation boards, the resulting complete circuitry setup was as shown in Figure 148.

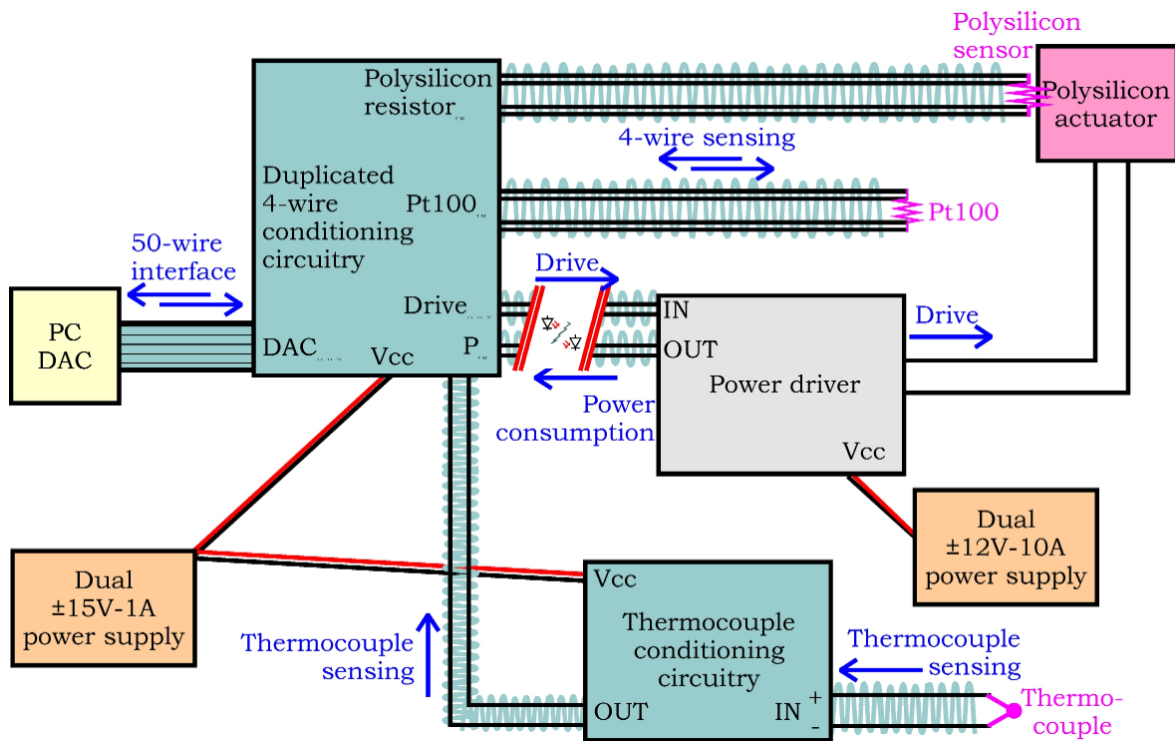


Figure 148 - Circuit interconnection diagram for photo-electrically insulated sensing and driving circuitries.

Initial functional tests

Sensor-actuator test

Using the previously calibration-derived (see p.251) third-order polynomial interpolations and the new circuitry setup, a preliminary test of active PCR-chips working in dual (sensor-actuator) mode was carried out with the clamped Pt100 sensor as an external control check. The plot in Figure 149 demonstrated the validity of the ground isolation circuitry setup, and prompted to the first functional PCR tests using active chips as fully independent devices.