ISL71590SEHEV1Z

Evaluation Board

AN1844
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Circuit Comments

The ISL71590SEH is an integrated-circuit temperature sensing transducer which produces an output current proportional to absolute temperature. The device acts as a high impedance constant current regulator passing 1µA/Kelvin for supply voltages between +4V and +33V.

The ISL71590SEHEV1Z evaluation platform supports the ISL71590SEH by highlighting four common application configurations. The evaluation board is composed of two ISL71590SEH devices, both of which can be individually heated and with a slotted PCB they are thermally isolated from each other.

With jumpers for circuit configuration, the four applications demonstrated are; single temperature sensor; lowest temperature in an array; average temperature in an array and differential temperature. These are illustrated in Figures 3 through 11 with supporting text accompanying each figure.

The configuration jumpers are grouped by application circuit so populating all the jumpers within a defined and labeled area configures the evaluation board for a particular functional configuration.

See Figure 1 for the ISL71590SEHEV1Z photograph.

The ISL71590SEHEV1Z sensors are potted with resistor heaters in Arctic Alumina Thermal Adhesive to simulate an installed application. In real world applications, as examples the sensors may be embedded in hollow metal probe sleeves, bolts or fastened to plate surfaces.

This user guide walks through each of the four applications illustrating noteworthy observations of each.

All evaluations and results in this document are done in still air.

Table 1 explains the ISL71590SEHEV1Z connections.

TABLE 1. ISL71590SEHEV1Z CONNECTIONS

BOARD CONNECTION NAME	DESCRIPTION AND FUNCTION
V+	V+ connection to ISL71590SEH and op-amp V+ bias.
V-/GND	Negative voltage connection to ISL71590SEH and negative bias to op-amp when evaluating differential temperature configuration.
I_{OUT} * R	Output used for single, average and lowest temperature configurations, $V_{OUT} = I_{OUT} * R$.
AMP V-	Connect to 0V when evaluating differential temperature configuration with op-amp.
DIFFERENTIAL OUT	Output used when evaluating differential temperature configuration.
HEATER 1	U1 heater voltage connection.
HEATER 2	U2 heater voltage connection.

Table2 illustrates the jumper installation definitions.

The ISL71590SEHEV1Z is shipped in single sensor configuration.

TABLE 2. JUMPER CONFIGURATION

SINGLE SENSOR TEMPERATURE	LOWEST TEMPERATURE (SERIES)	AVERAGE TEMPERATURE (PARALLEL)	DIFFERENTIAL TEMPERATURE
JP8	JP4, JP5	JP3, P8	JP2, JP6, JP7, J P9
Connects U1 to R3	Connects U1 and U2 in series to R3	Connects U1 and U2 in parallel to R3	Connects R2, U2, op-amp and U1 to a common node

NOTE: Install HEATER 1 and HEATER 2 jumpers to heat U1 (left) and U2 (right) ISL71590SEH respectively.

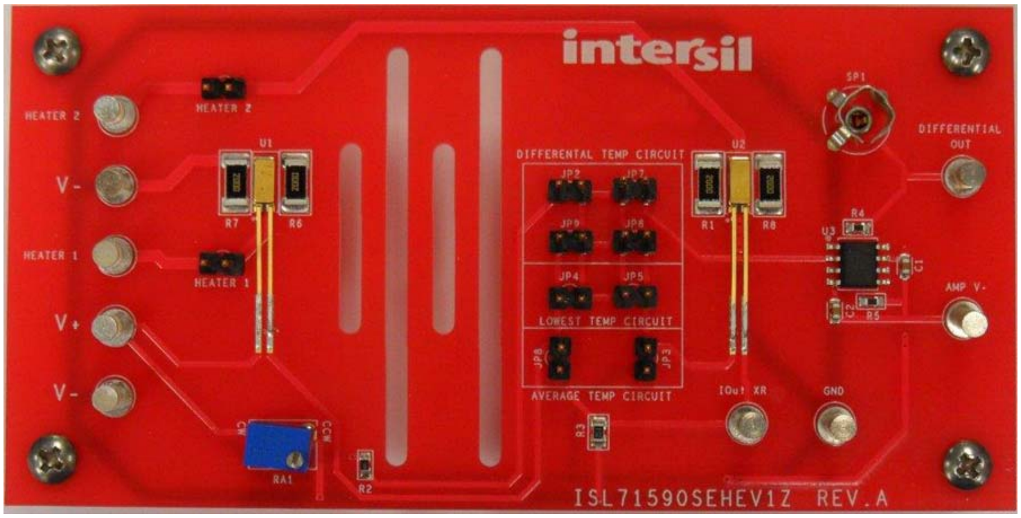

FIGURE 1. ISL71590SEHEV1Z EVALUATION BOARD

Typical Applications

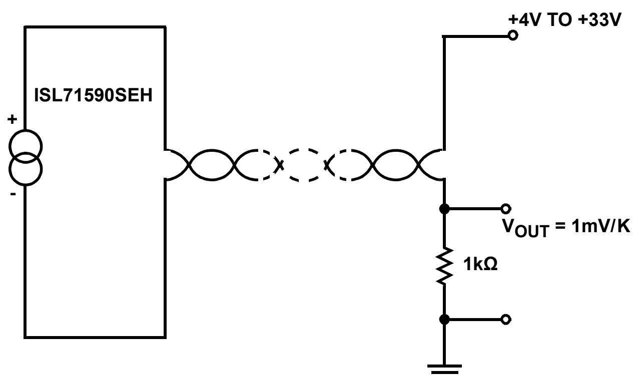

FIGURE 2A.

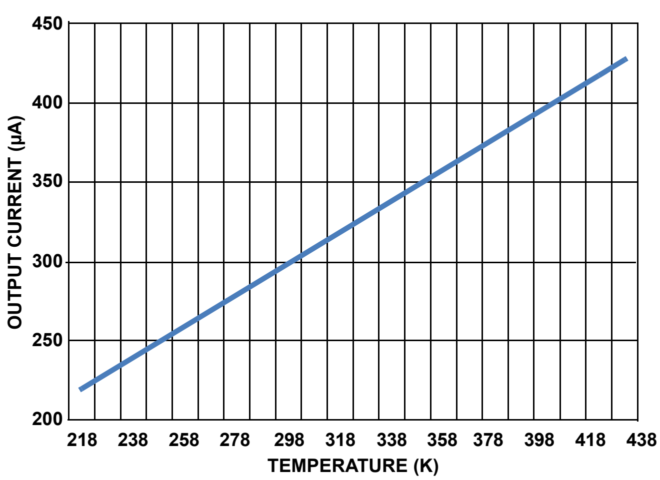

FIGURE 2B.

FIGURE 2. SINGLE SENSOR OUTPUT CURRENT IS PROPORTIONAL TO ABSOLUTE TEMPERATURE

Connecting just a single ISL71590SEH and resistor as shown in Figure 2A provides the simplest single temperature sensing implementation. The resulting over-temperature output current is shown in Figure 2B illustrating the 1µA/Kelvin (K) linear performance across the entire operating range of temperature.

For the single sensor configuration, Figure 3 shows the V_{OUT} increasing once the heater is turned on, the temperature increases over time rising from the ambient +25°C (298.15K) to a peak temperature of ~+100°C (373K) when the heater is turned off and both the V_{OUT} and temperature decreases. The output current change in this example is 1µA/Kelvin, resulting in a 1mV/°C or 1mV/K change with a 1kΩ V_{OUT} resistor. Increasing the V_{OUT} resistor value increases the measurement resolution.

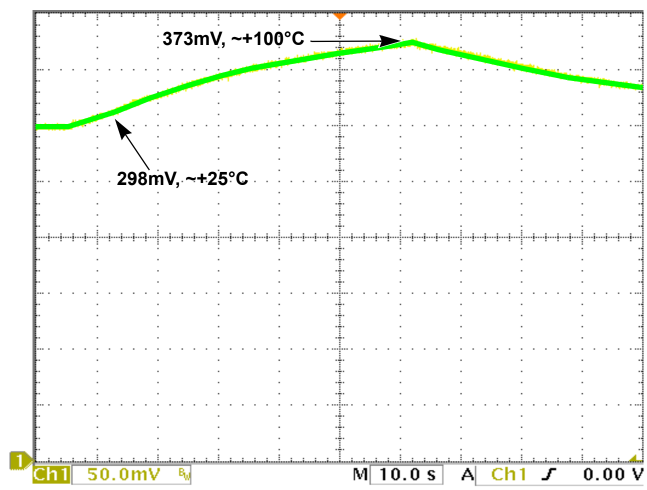

FIGURE 3. SERIES CONFIGURATION FOR MINIMUM TEMPERATURE

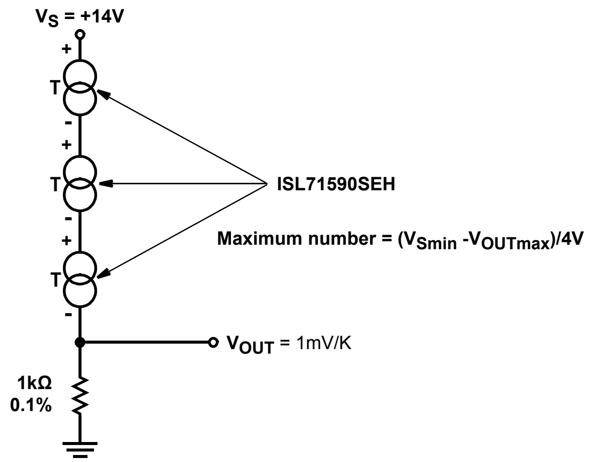

FIGURE 4. LOWEST TEMPERATURE SENSING SCHEME. AVAILABLE CURRENT IS THAT OF THE “COLDEST” SENSOR

Connecting several ISL71590SEH temperature sensors in series, as shown in Figure 4, results in the lowest individual temperature in the array to be indicated, since the series output current will be constrained by the sensor exposed to the lowest individual temperature. The maximum number of sensors in any single resistor string is limited by the total voltage applied divided by 4V as each device needs to be adequately biased when the temperature is the same or similar across all sensors.

As the higher temperature device(s) tries to output more current, it is prevented from doing so by the series current of the lowest temperature device and the result is that the voltage across the higher temperature device(s) decreases to the minimum operational voltage.

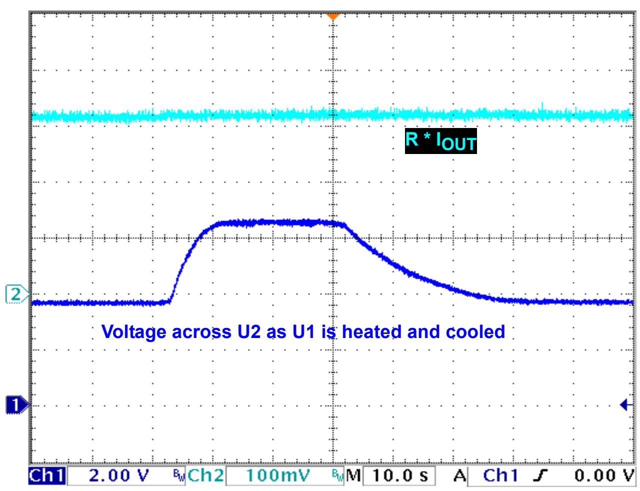

FIGURE 5. ISL71590SEH IN SERIES CONFIGURATION SHOWING VOLTAGE AROSS COOLER SENSOR

In Figure 5 the resultant I_{OUT} x R_{OUT} and the voltage across U2 are shown. As U1 is first heated then cooled to show the relationship between the coolest sensor which provides the output current level and the voltage across the cooler of the two sensors. Note that the output voltage representing the coolest temperature in the series array does not change. The coolest sensor will be the one with the highest voltage across it as the others are in a collapsed state as they attempt to provide more current than the minimum sensor is providing. Total voltage across string is 10V.

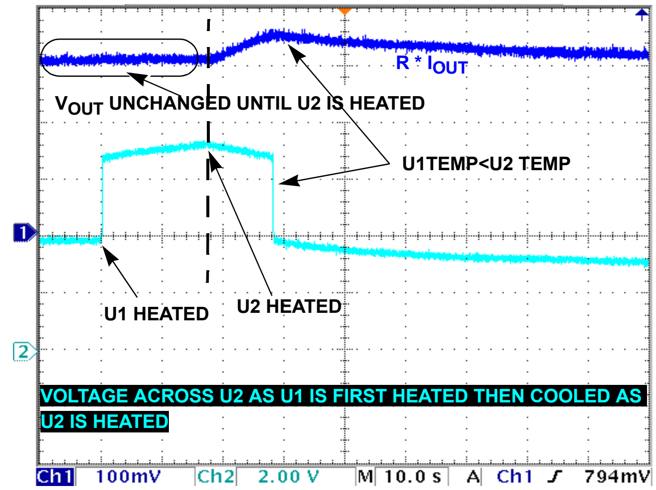

FIGURE 6. ISL71590SEH IN SERIES CONFIGURATION SHOWING VOLTAGE ACROSS COOLER SENSOR

Figure 6 shows the voltage across U2 and the resultant I_{OUT} x R_{OUT}. U1 is first heated and then cooled as U2 is heated. Here the V_{OUT} is unchanged until the second sensor is heated, then it rises reflecting the lower temperature is rising as U2 is heated. As the decreasing U1 temperature falls below the U2 increasing temperature, the V_{OUT} decreases and the voltage across U2 collapses as U1 is now the cooler dominant device. Total voltage across string is 10V.

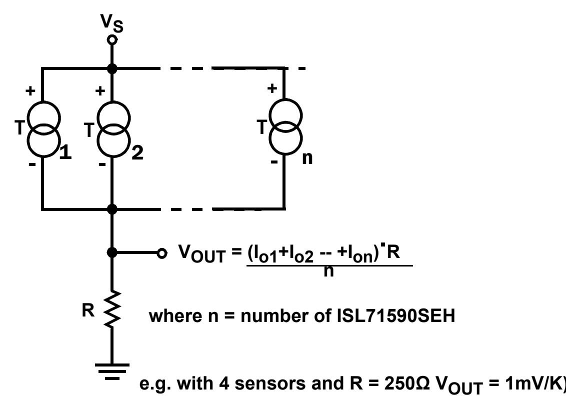

FIGURE 7. AVERAGE TEMPERATURE SENSING SCHEME

In contrast, connecting several temperature sensors in parallel as in Figure 7, results in the sum of the individual output currents flowing through the output resistor. This allows for the average temperature of the array to be expressed as a voltage. The value of the resistor must be appropriately low enough to ensure adequate voltage across the entire array. Keeping the output voltage at the same scale as in Figures 2 and 4 the value of the resistor R is chosen by the formula shown in Equation 1:

$$R = \frac{1k\Omega}{n} \quad \text{(EQ. 1)}$$

where n = the number of sensors.

Figure 8 shows the result of the parallel array configuration that returns the average temperature of the array as each ISL71590SEH in the evaluation board array outputs a current relative to its individual temperature. The sum of these currents flow through the output resistor, resulting in a V_{OUT} voltage that represents the average of all sensor temperatures expressed in Kelvin when the V_{OUT} is divided by the number of sensors in the parallel array.

The V_{OUT} is 596mV when both sensors are at +25°C, each sensor outputting 298µA of current into the 1kΩ resistor. When one temperature sensor is heated, the average temperature increases resulting in the V_{OUT} increasing, representing the average of the two ISL71590SEH temperatures. In Figure 8 the V_{OUT} rises to 686mV representing an average temperature of 70°C (343K).

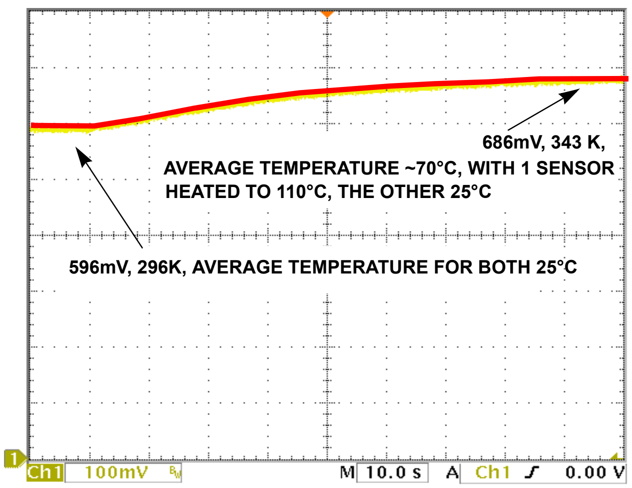

FIGURE 8. ISL71590SEH IN PARALLEL CONFIGURATION SHOWING VOLTAGE REPRESENTING THE TOTAL ARRAY CURRENT

For measuring a maximum temperature, individual sensors can be employed in an array but must then be multiplexed to a common output resistor and periodically polled for the individual temperatures to be monitored.

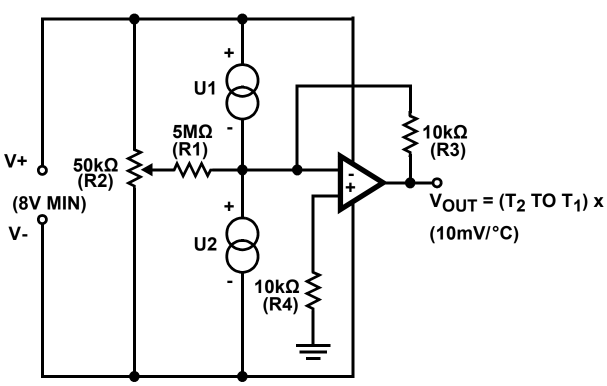

FIGURE 9. DIFFERENTIAL THERMOMETER

Figure 9 illustrates a simple circuit useful for measuring differential temperatures. R2 is used to trim the output of the op-amp to a desired differential temperature reference.

Any output voltage deviation in either polarity from that reference voltage is then an indication of a change in the differential temperature between the two sensors.

For example, with the output trimmed to 0mV and U2 sensing the reference temperature when U1 is cooled below the temperature of the U2 reference temperature, the op-amp output will decrease to a negative polarity indicating that the measured temperature is less than the reference. Conversely an increase in U1 temperature would result in the op-amp output voltage moving in a positive direction.

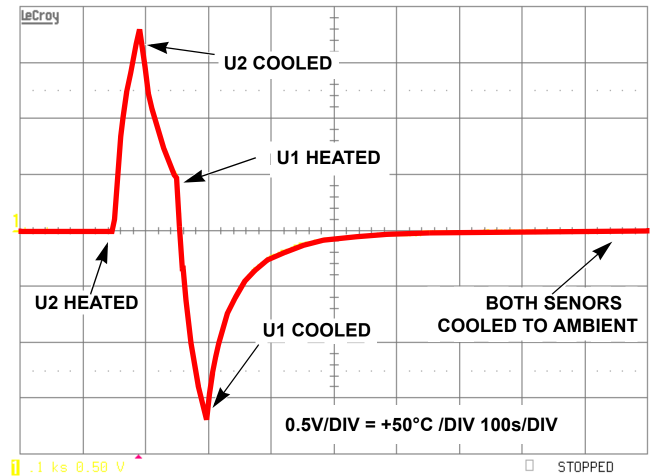

FIGURE 10. ISL71590SEH DIFFERENTIAL CONFIGURATION OPERATION

Figure 10 displays the output of the differential temperature configuration as shown in Figure 9 with U1 held as the temperature reference and U2 then U1 being alternately heated. Here the op-amp output moves in proportion to and in the direction of the change in differential temperature relative to the reference sensor. Starting with the differential temperature set to 0°C, at an ambient room temperature U2 is first heated until it reaches a temperature of ~ 200°C when the heater is turned off, U1 is then heated as U2 is cooling driving the output in the opposite polarity as U1 temperature now exceeds U2. Both sensors are then allowed to cool, returning to within 0.2°C differential temperature at the end of the trace and eventually to 0.01°C where it started.

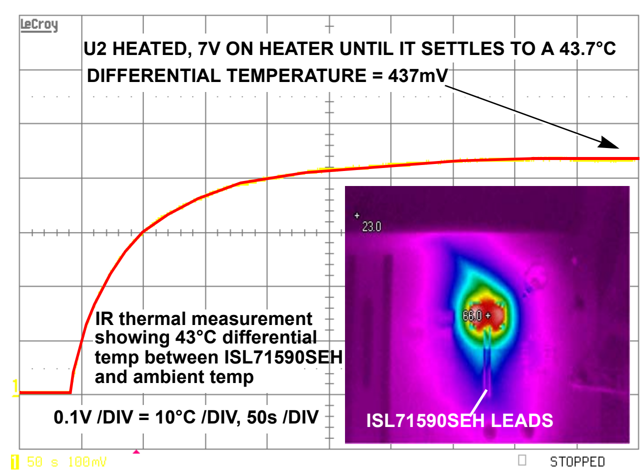

FIGURE 11. ISL71590SEH DIFFERENTIAL CONFIGURATION ACCURACY

The Figure 9 circuit has an output voltage deflection of 10mV/°C when either U1 or U2 is held as the reference. Figure 11 illustrates that with both the differential circuit output voltage and with an IR thermal image this is true. In the IR image, the ISL71590SEH location is shown to be 66°C and the ambient shown in top left corner to be 23°C. To optimize the accuracy of the temperature measurements, high precision resistors with a low temperature coefficient are recommended such as 0.01% metal film or metal strip types for the output resistor.

When in the differential temp configuration connect +10V to V+ test point, -10V to V- test point and connect GND (0V) to AMP V- test point.

On the ISL71590SHEV1Z, each ISL71590SEH device has an on board heater allowing each to be independently heated to different temperatures by adjusting the heater voltage for each. The heaters are two 200Ω SMD resistors mounted on each side of the temperature sensor. Table 3 provides a guide for heater voltage to approximate temperature increase that the sensor will be exposed to in the epoxy embedded assembly.

TABLE 3. HEATER VOLTAGE GUIDE

HEATER VOLTAGE (V)	APPROXIMATE TEMPERATURE INCREASE (°C)
3	9
5	24
7	43
9	73

Using the PCB heaters allows a quick demonstration of the four functional configurations, observing the V_{OUT} changes with a voltmeter or oscilloscope as appropriate.

ISL71590SEHEV1Z

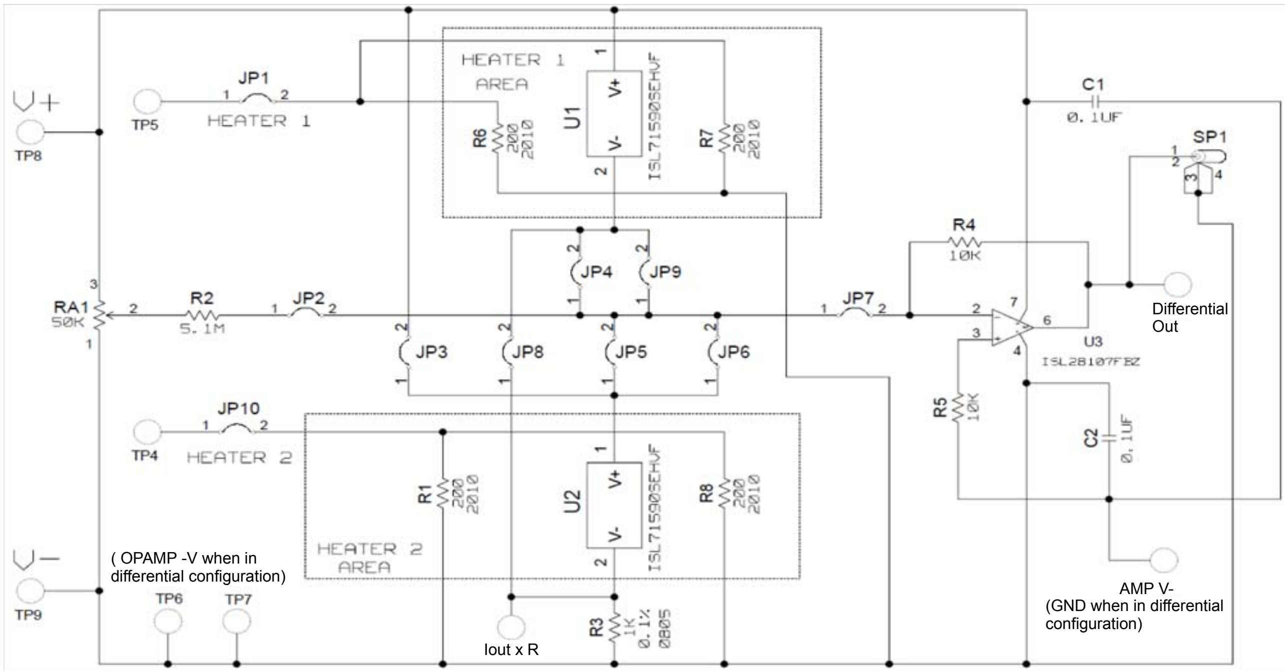

FIGURE 12. ISL71590SEHEV1Z SCHEMATIC

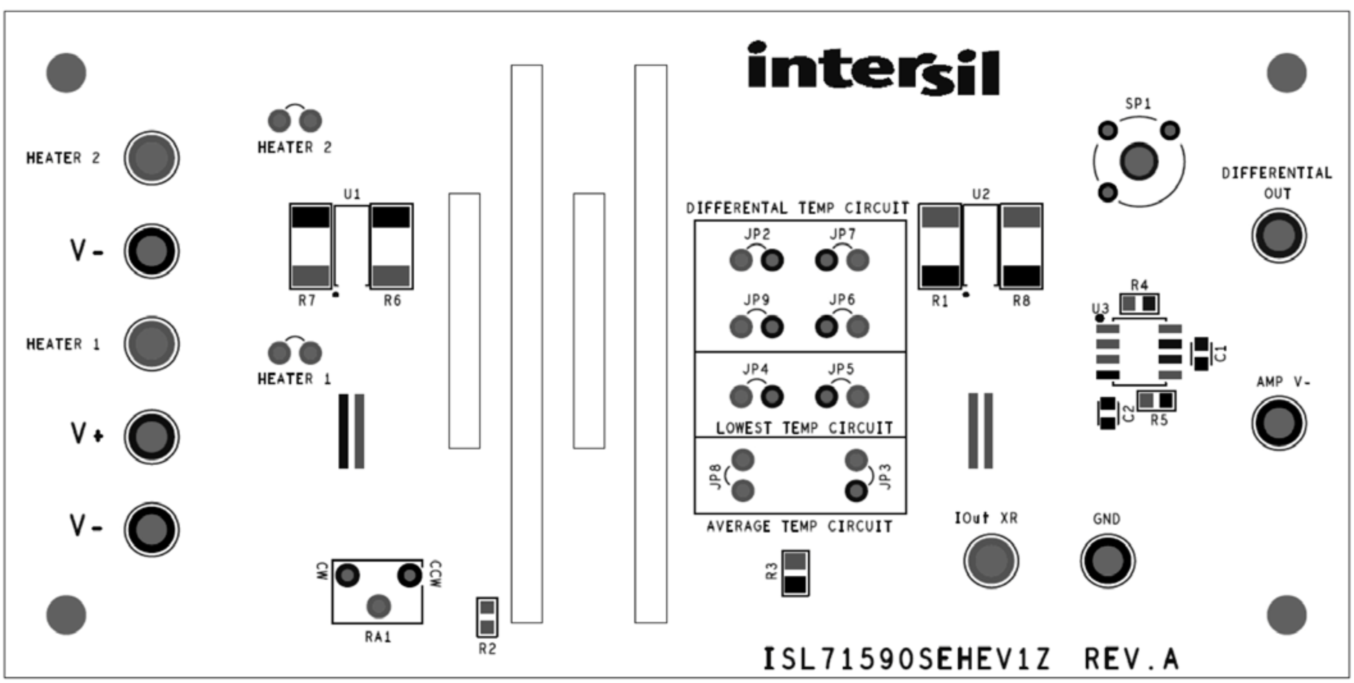

FIGURE 13. ISL71590SEHEV1Z TOP LEVEL PCB PATTERN

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Refer to "http://www.renesas.com/" for the latest and detailed information.

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