

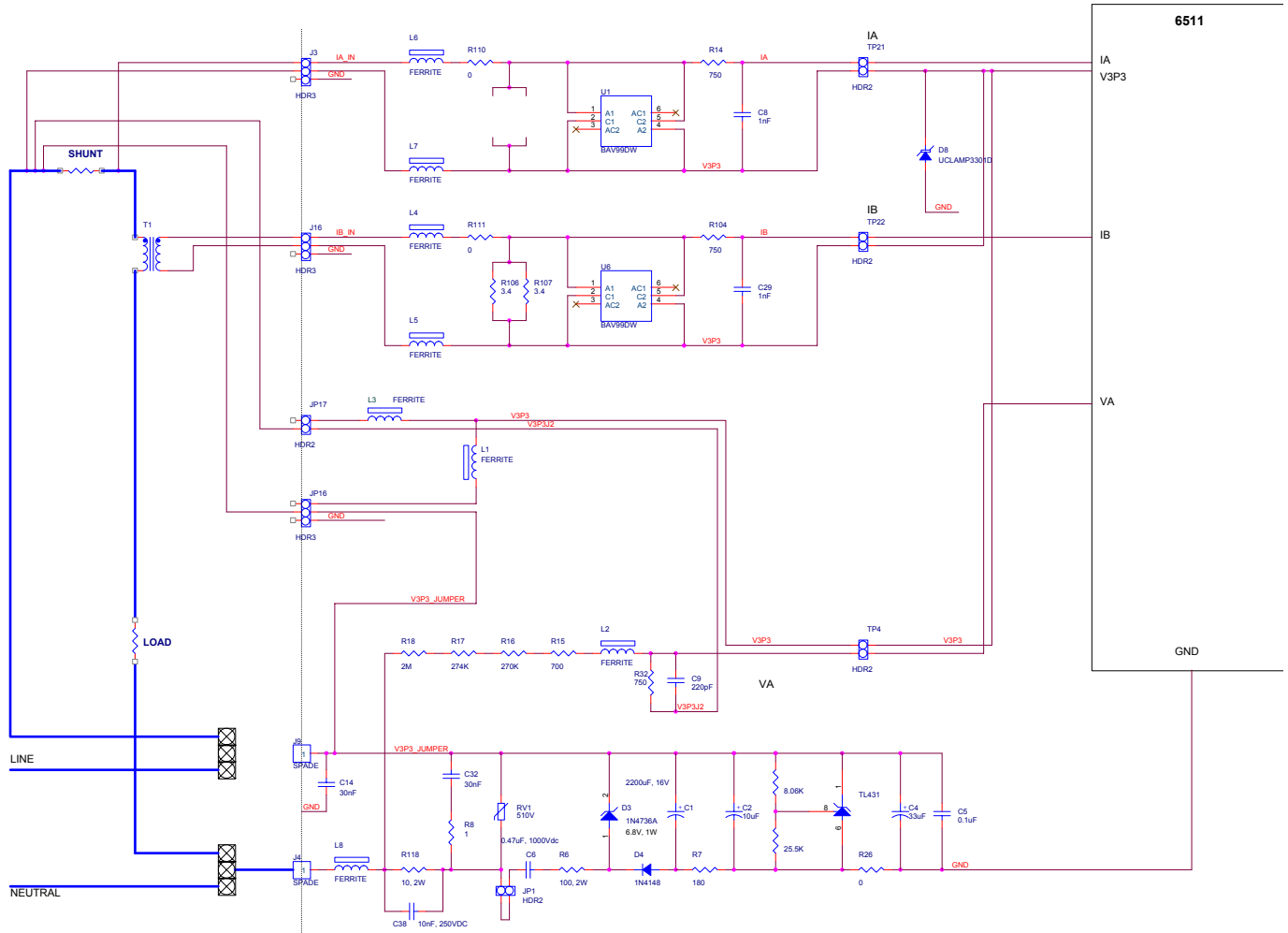
Calibration of a Single Phase Meter with Shunt and CT

Single-phase residential meters use a shunt resistor combined with a current transformer (CT) in order to enable tamper-detection. This application note describes the calibration procedure and the method to compute billing values for single phase metering.

The second part of this application note describes common methods of tampering and ways to detect tampering.

6511 Calibration for Shunt and CT

Block Diagram:



Note: The reference designators in this Block Diagram apply to the 2-layer 6511 Demo Board.

Definitions and Procedure:

1. Set the meter equation field of the configuration RAM for *EQU* to zero using the command:

```
RI00 = 10 // EQU = 0; CE_EN = 1; TMUX = 0;
```

2. The shunt resistor is connected to Phase 0 (channel A), and the CT is connected to Phase 1 (channel B).
The calibration procedure described in next section is applicable to this sensor arrangement. But one can easily modify this procedure to the desired CT/Shunt combinations.
3. For the sake of calculation, individual *WRATE* parameters for Pulse generation, i.e. *WRATE_SHUNT* and *WRATE_CT* will be used.
4. It is also necessary to compute and estimate *IMAX_SHUNT* and *IMAX_CT* parameters for meter billing purposes.
5. Using *IMAX_SHUNT* and *VMAX*, the energy calculations for channel A should be performed.
6. Using *IMAX_CT* and *VMAX*, the energy calculations for channel B should be performed.
7. The LSB values for measurements for *W0SUM* / *W1SUM* / *VAR0SUM* / *VAR1SUM* / *I0SQSUM* / *I1SQSUM* / *V0SQSUM* should be modified to compute the correct energy values. That is, *IMAX_SHUNT* and *IMAX_CT* should be applied separately to individual channels based on the sensor connections.
8. Before starting a calibration it should be ensured that all coefficients are in their default state, i.e. *CAL_IA* (0x08), *CAL_VA* (0x09), *CAL_IB* (0x0a) must be 16384. *PHADJ_A* (0x0e) and *PHADJ_B* (0x0f) should be zero.
* (0x0p) represents the CE register address.

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Calibrating for Shunt Resistor (Channel A):

1. Estimate $IMAX$ for the shunt resistor ($IMAX_SHUNT$). This can be done by using the following formula:

$$IMAX_SHUNT = V_{iMAX}/R_{SHUNT}$$

---This adjusted $IMAX$ value is stored as $IMAX_SHUNT$ at the MPU address location that can be updated using the command **)A= $IMAX_SHUNT$** of the Demo Code supplied by TERIDIAN.

---The V_{iMAX} value is the maximum analog input voltage for the channel, typically 176mV (RMS).

2. Apply $VMAX = 600V$ (RMS) for the 6511 Demo Board if the resistor divider for VA has not been changed.
3. $WRATE_SHUNT$ is computed based on $IMAX_SHUNT$ and $VMAX$.
4. Update the CE $WRATE$ register (0x2D) with $WRATE_SHUNT$.
5. Test for accuracy at 15A, 240V at phase angle 0, phase angle 60 and at phase angle -60 degrees.
6. Apply the error values to the supplied spreadsheet (revision 2.0 or later) and determine the calibration coefficients for channel A, i.e. CAL_IA , CAL_VA , and $PHADJ_A$.
7. Update the CE registers 0x08, 0x09 and 0x0E of the compute engine with the calibration coefficients obtained from the spreadsheet, using the commands **]8= CAL_IA** , **]9= $CALVA$** , and **]E= $PHADJ_A$** .
8. Retest for accuracy at several currents and phase angles.

Calibration for CT (Channel B):

1. Assign/compute $IMAX$ for the CT channel ($IMAX_{CT}$), based on the CT turns ratio N and the termination resistor value $R_{Termination}$ using the formula:

$$IMAX_{CT} = 176mV * N / (R_{Termination})$$

This $IMAX$ value is stored as $IMAX_{CT}$.

2. Compute $WRATE_{CT}$ based on the $IMAX_{CT}$ and $VMAX$.
3. Update the CE $WRATE$ variable with $WRATE_{CT}$.
4. Enter the command `>)7=2;` Configure $W1SUM$ as external pulse source since the CT is connected to Channel 1 for $VA * IB$.
5. Test for accuracy at 15A, 240V at phase angle 0, phase angle 60 and at phase angle -60 .
6. Apply these values to the supplied spreadsheet (revision 2.0 or later) and derive the calibration coefficients for $PHADJ_B$.
7. Update only the field Jf of the CE registers with the value for $PHADJ_B$.
8. CAL_{IB} should be adjusted for the total error found in the tests using the formula
$$CAL_{IB} = 16384 * (1 - error/100)$$
since CAL_{IA} and CAL_{VA} are already fixed by the sensor used on Phase A. That is, if the chip reports an error of -2.5% , CAL_{IB} should be adjusted for a value of $(16384 * (1 - (-2.5/100)))$.
9. Since CAL_{VA} is already adjusted, this register should not be updated.
10. Retest for accuracy at several currents and phase angles.

Tamper Detection Using CT and Shunt.

Tampering has become a common practice for reducing electricity consumption in single-phase metering. To prevent tampering, meter manufacturers opted for solid-state electricity meters. Teridian's 71M6511/6511H metering chip provides solutions to the meter manufacturers for tamper detection.

This part of the application note describes the details of tamper detection.

71M6511 is a single phase metering chip with provision for two current sensor inputs and one voltage input. Under normal operation the meter designed for tamper detection contains two current sensors and one voltage sensing input through the resistor dividers. The following sensor combinations can be used for tamper detection using the 71M6511 chip.

Combination	IA Input	IB Input
1	Current Shunt	Current Transformer
2	Current Transformer	Current Shunt
3	Current Transformer	Current Transformer

Please note that the option involving two current shunts is not allowed, since the shorting of live and neutral wires can occur with this combination. The metering Equation for supporting the above combination for tampering should be '0'. That is, the Compute Engine provides two output energy registers W0SUM_X ($VA * IA$) and W1SUM_X ($VA * IB$) using metering Equation '0' that can be used for tampering. The MPU firmware can easily be implemented for Tamper detection using the available Energy Registers.

Also please note that the VAR0SUM_X and VAR1SUM_X registers are also available if one wishes to implement tampering using VARhours.

Under normal operation the single-phase meter can be used for tamper detection with one of the above combination of sensors. Following is a diagram showing a single-phase meter connected as per combination 1 (from the above table). The meter equations are the same for all combinations provided in the above table.

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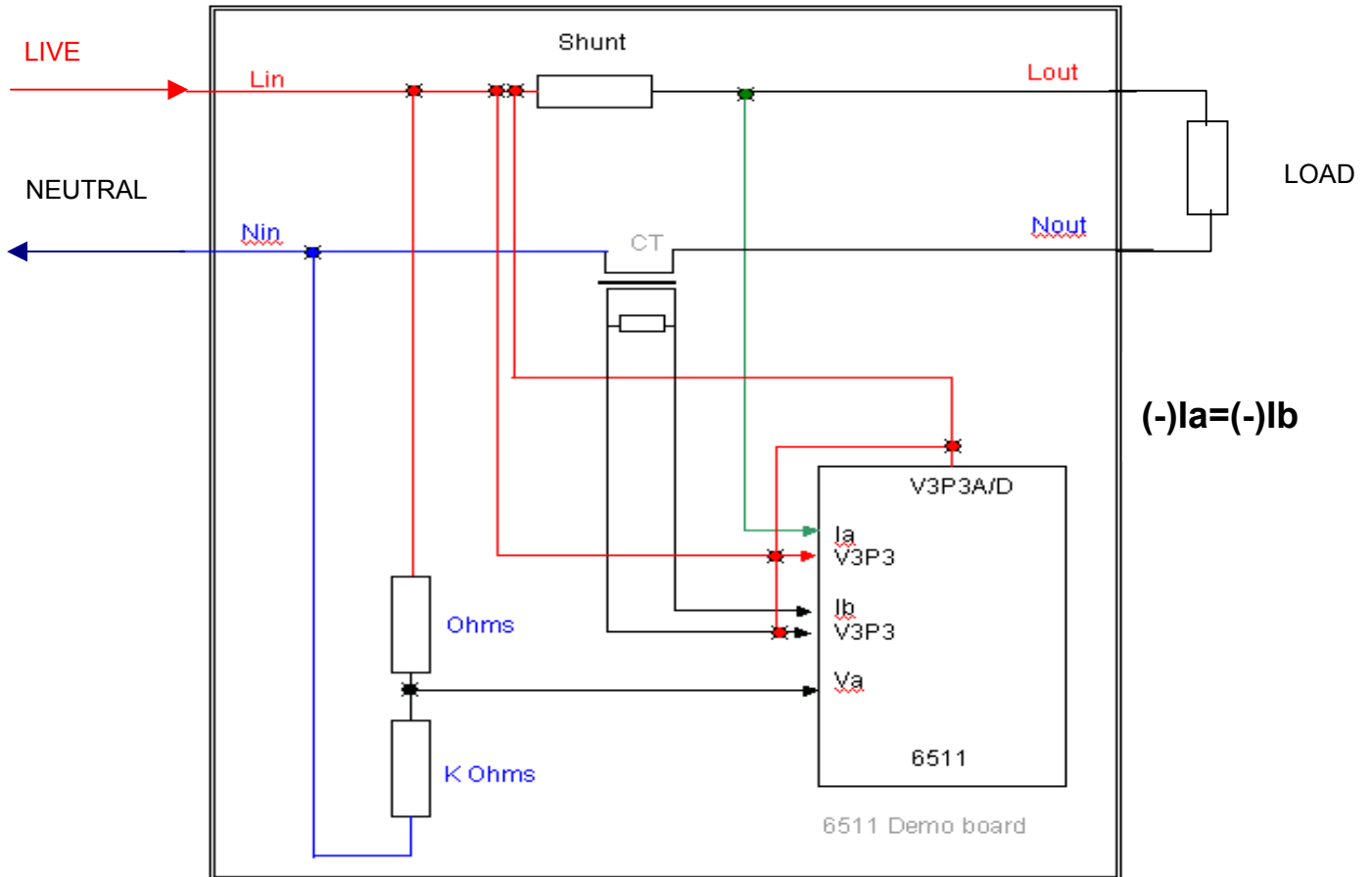


Figure 1: Single phase meter with two sensors under normal operation (no tampering)

The following diagrams show some of the possible tamper methods that can be prevented using the 71M6511/6511H with two current sensors. All diagrams provide the current measured for easy understanding of Tamper detection.

6511 Calibration for Shunt and CT

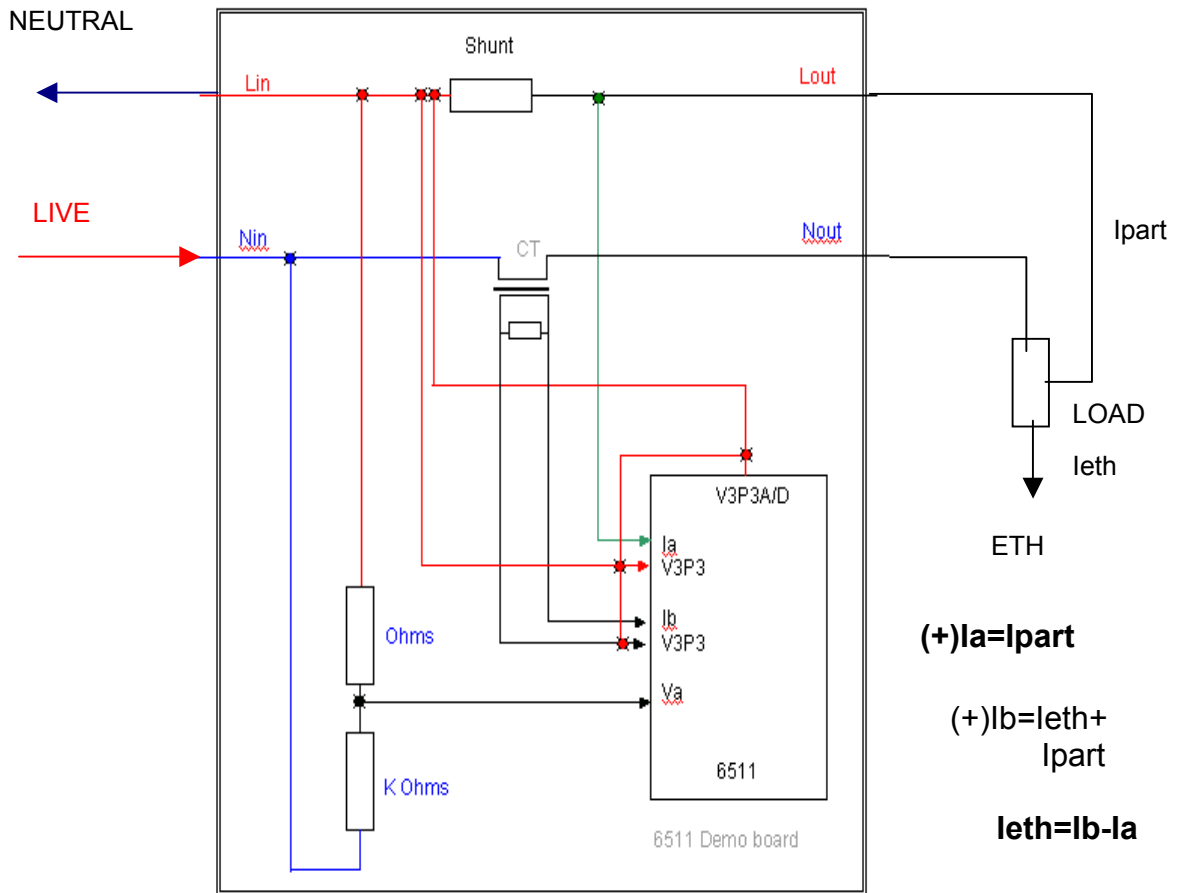


Figure 3: Tamper method #2, L and N swapped, load partially connected to GND.

6511 Calibration for Shunt and CT

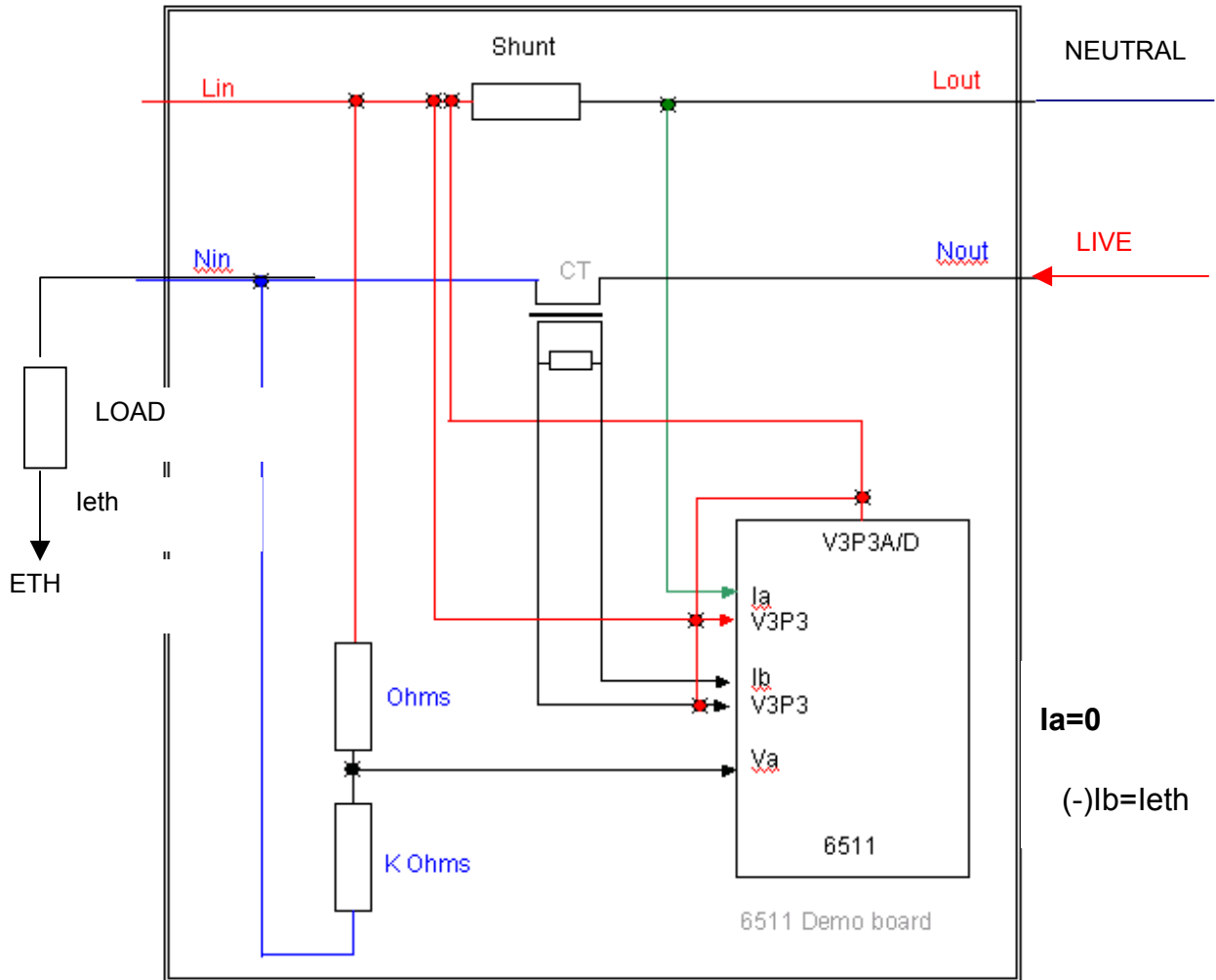


Figure 4: Tamper method #3, L and N swapped, I/O swapped, LOAD connected to GND.

6511 Calibration for Shunt and CT

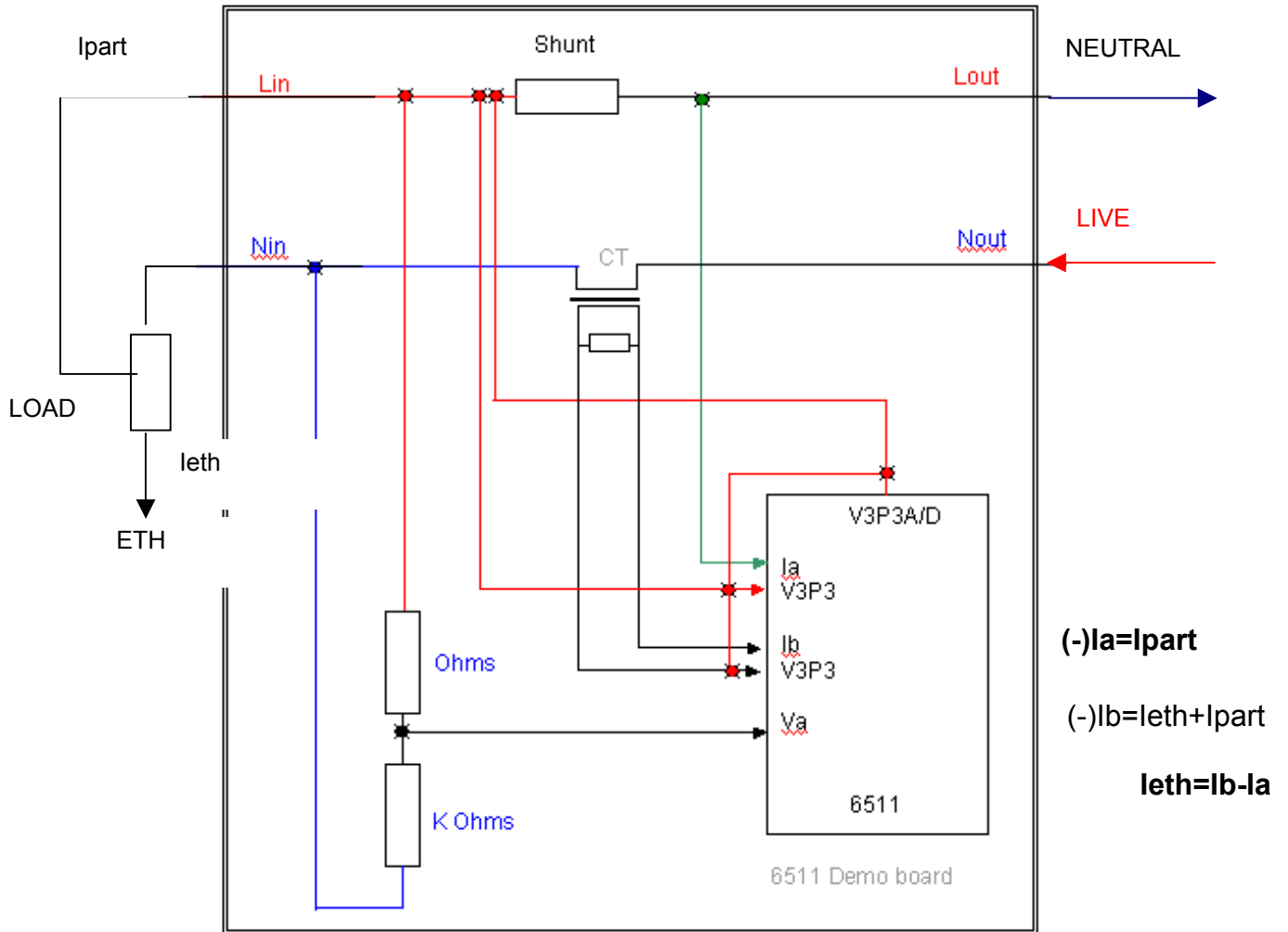


Figure 5: Tamper method #4, L and N swapped, I/O swapped, LOAD partially connected to GND.

6511 Calibration for Shunt and CT

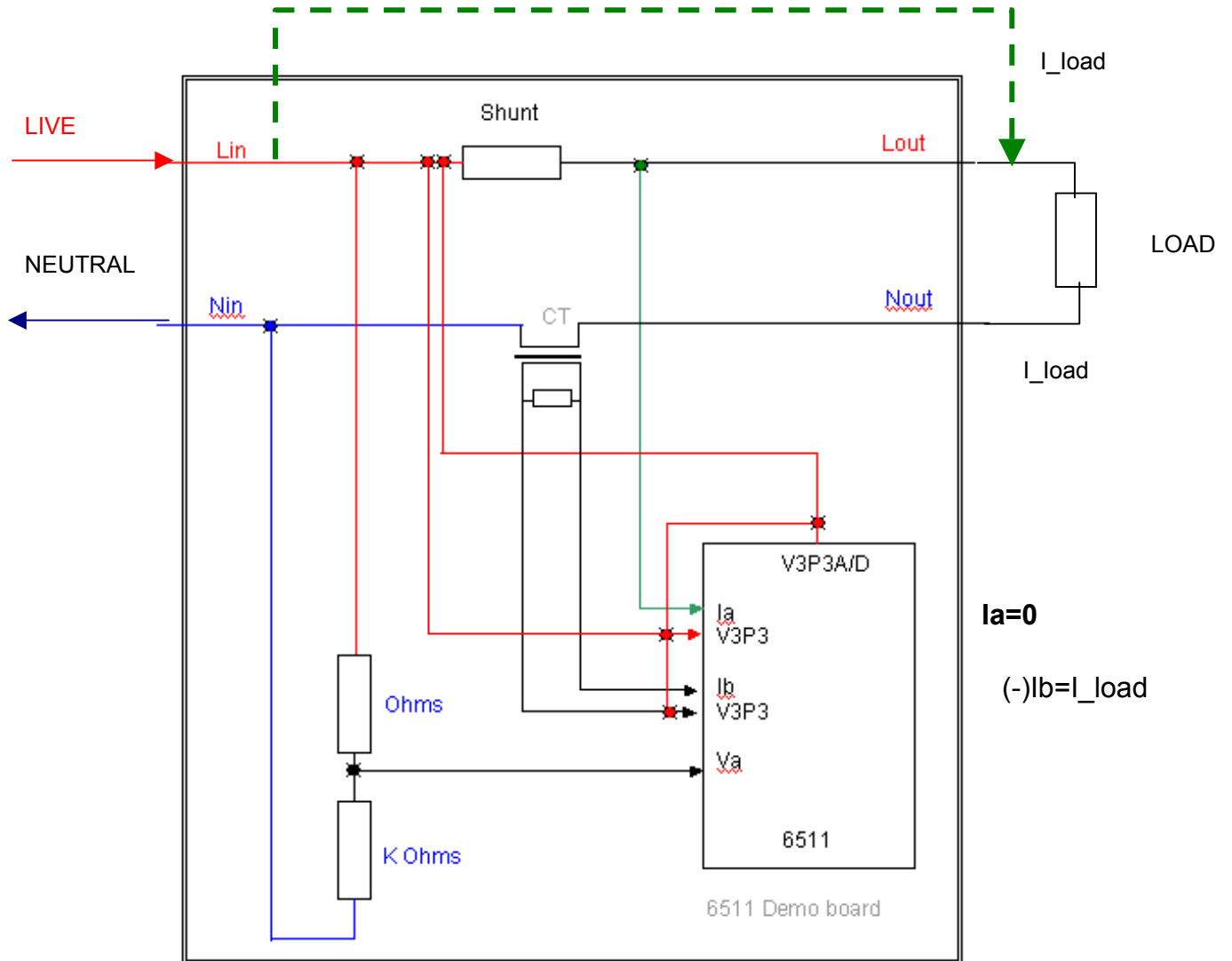


Figure 6: Tamper method #5, Lin and $Lout$ externally shorted ($Lin=Lout$).

6511 Calibration for Shunt and CT

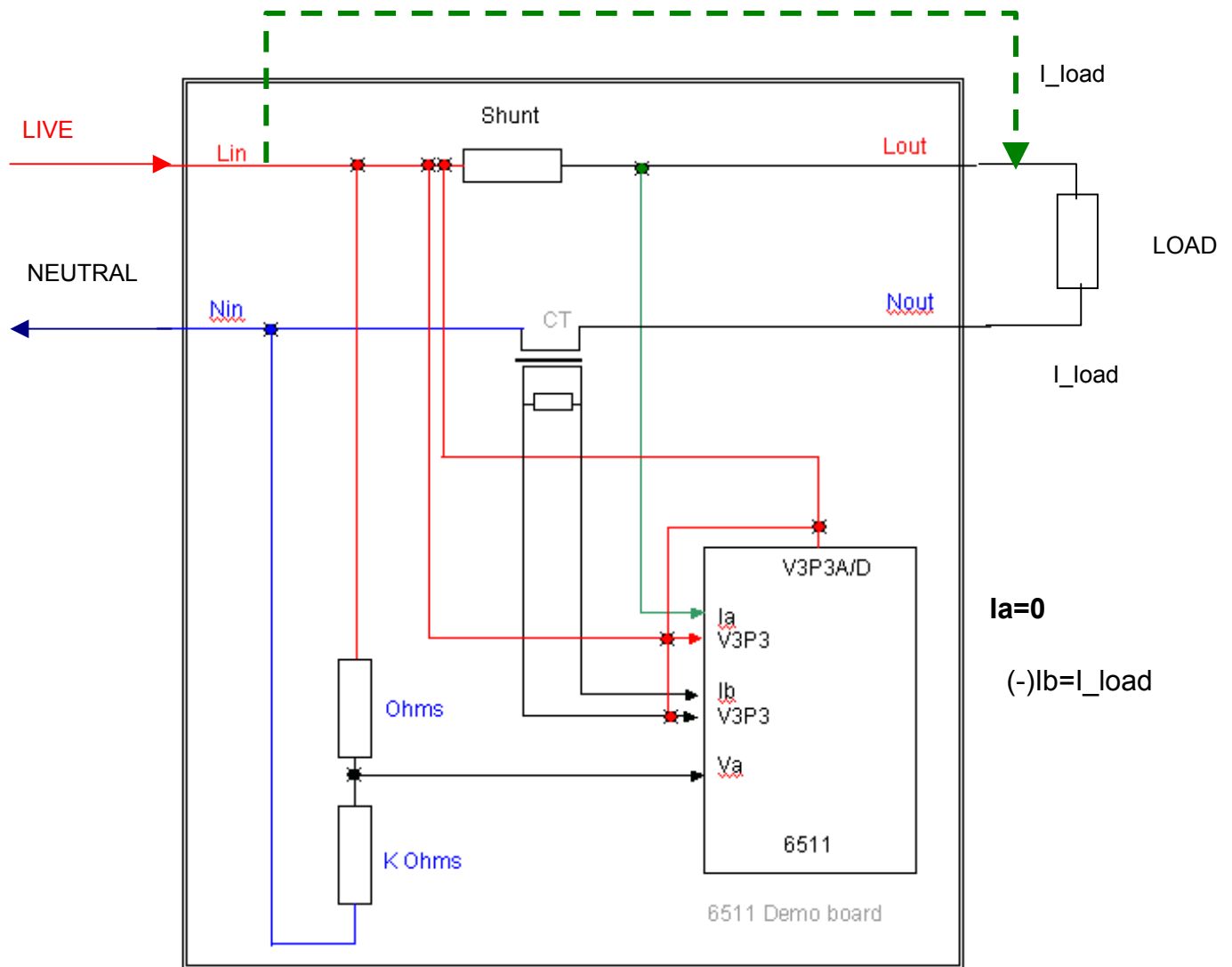


Figure 7: Tamper method #6, Lin and Lout externally bypassed (Lin=Lout).

6511 Calibration for Shunt and CT

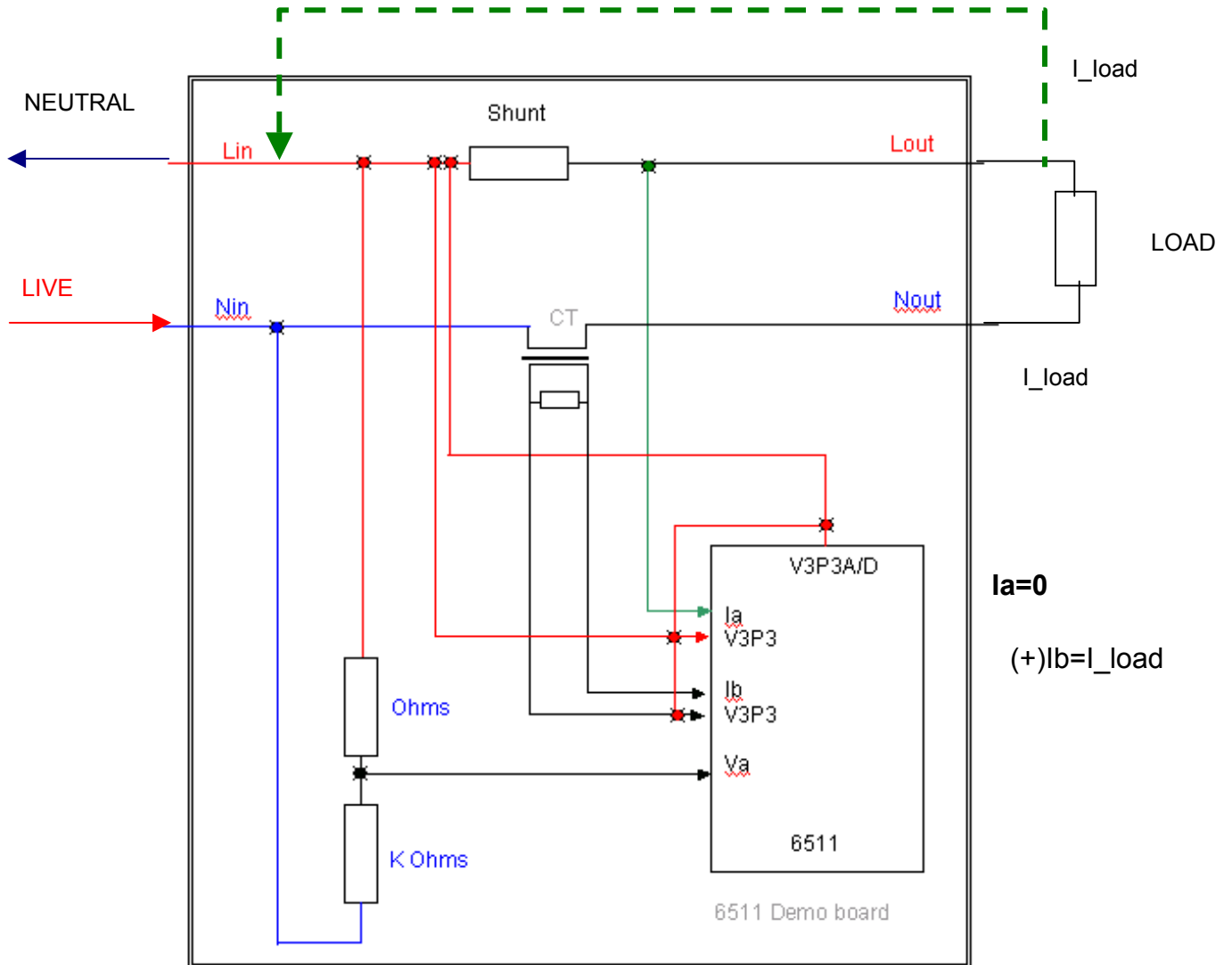


Figure 8: Tamper method #7, L and N swapped, L_{in} and L_{out} externally bypassed ($L_{in} = L_{out}$).

6511 Calibration for Shunt and CT

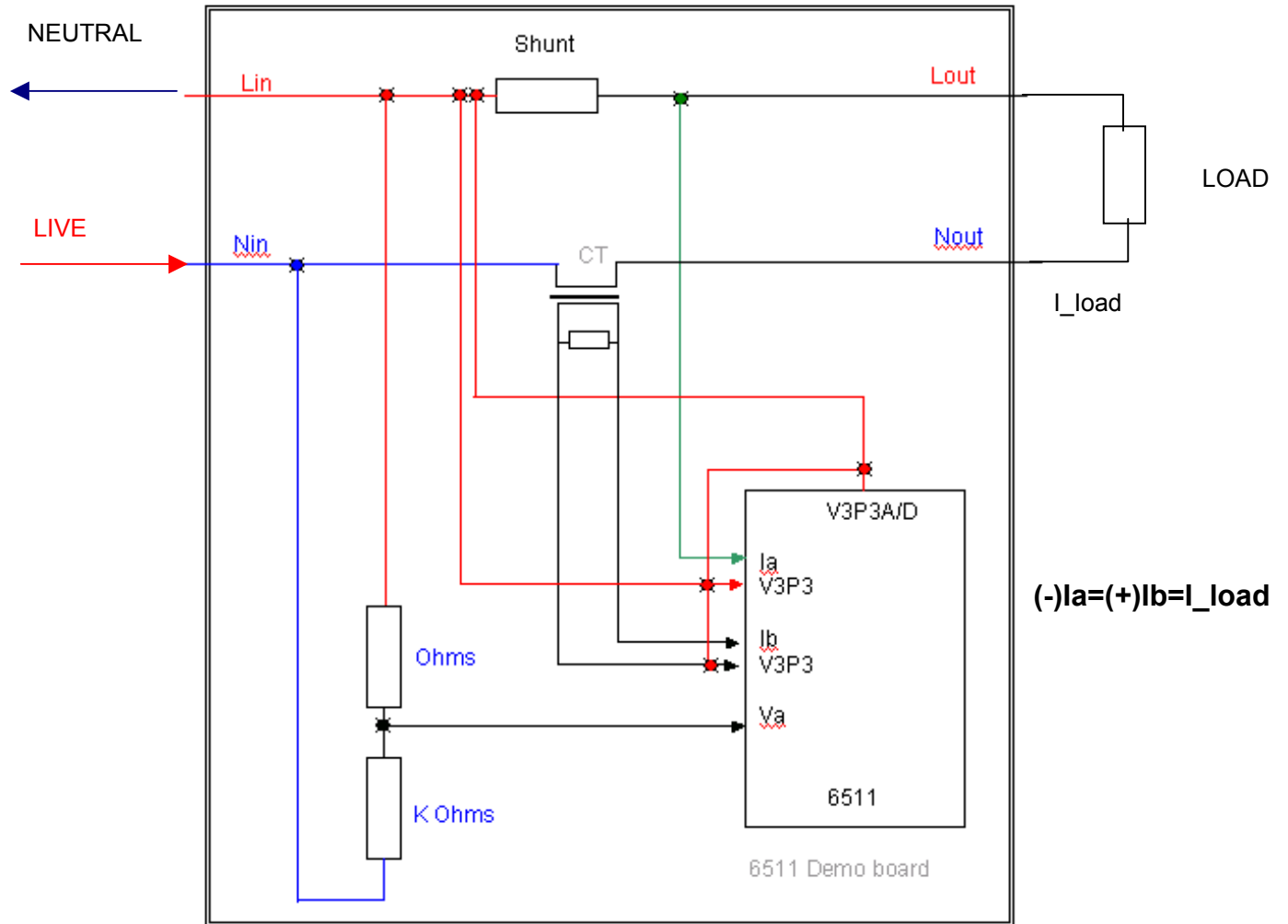


Figure 9: Tamper method #8, L&N swapped.

6511 Calibration for Shunt and CT

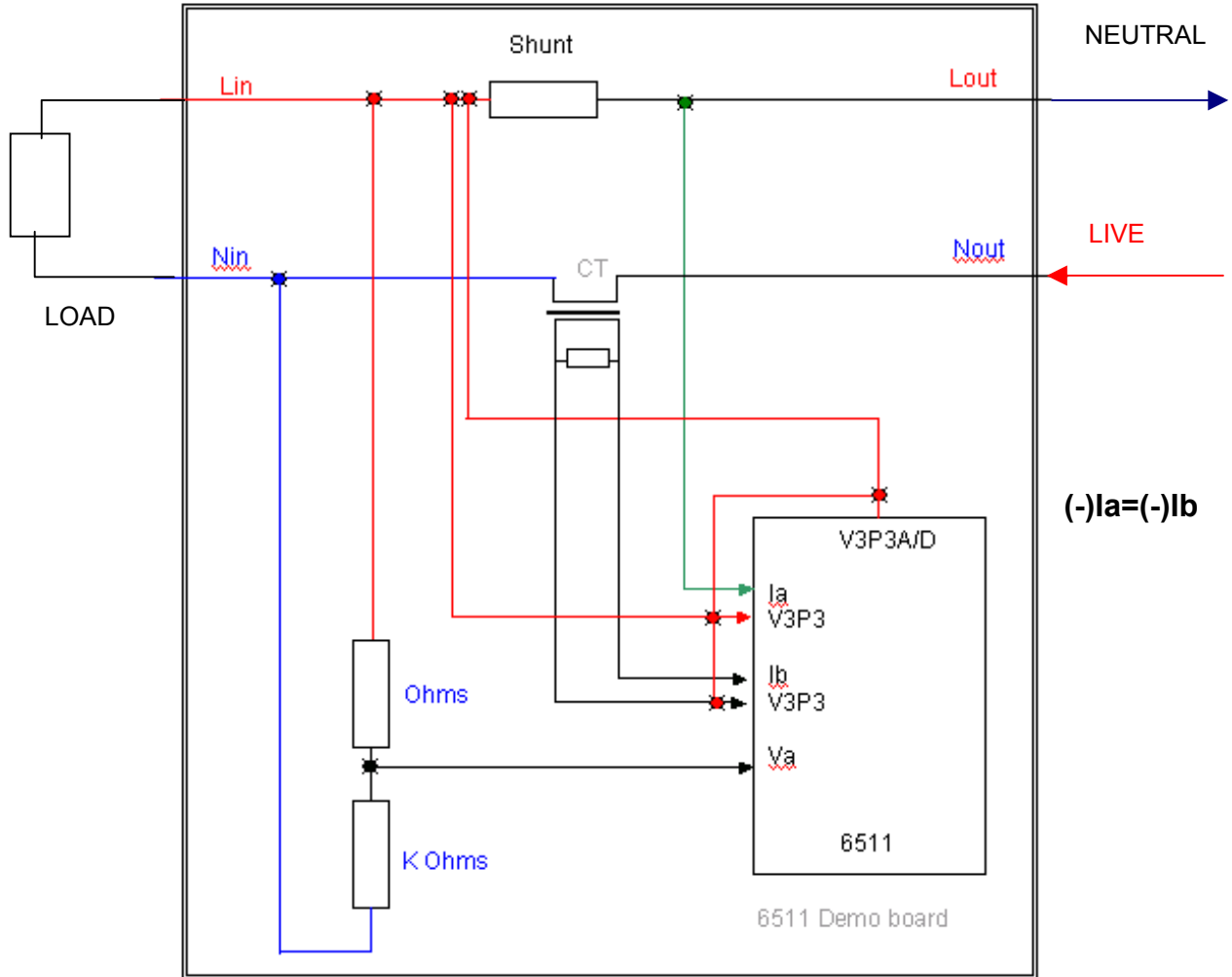


Figure 10: Tamper method #9, L and N swapped, I/O swapped

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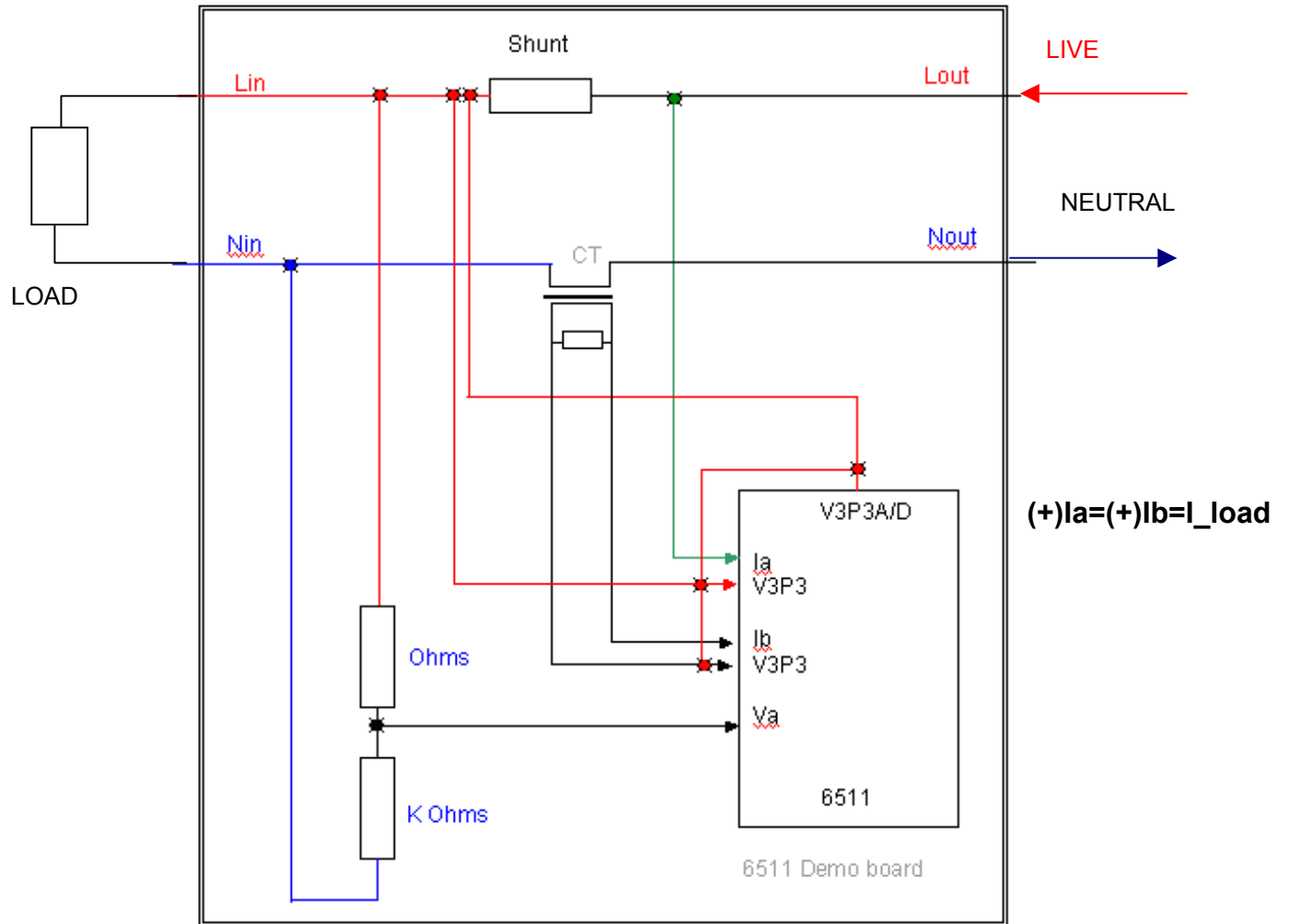


Figure 11: Tamper method #10, I/O swapped.

6511 Calibration for Shunt and CT

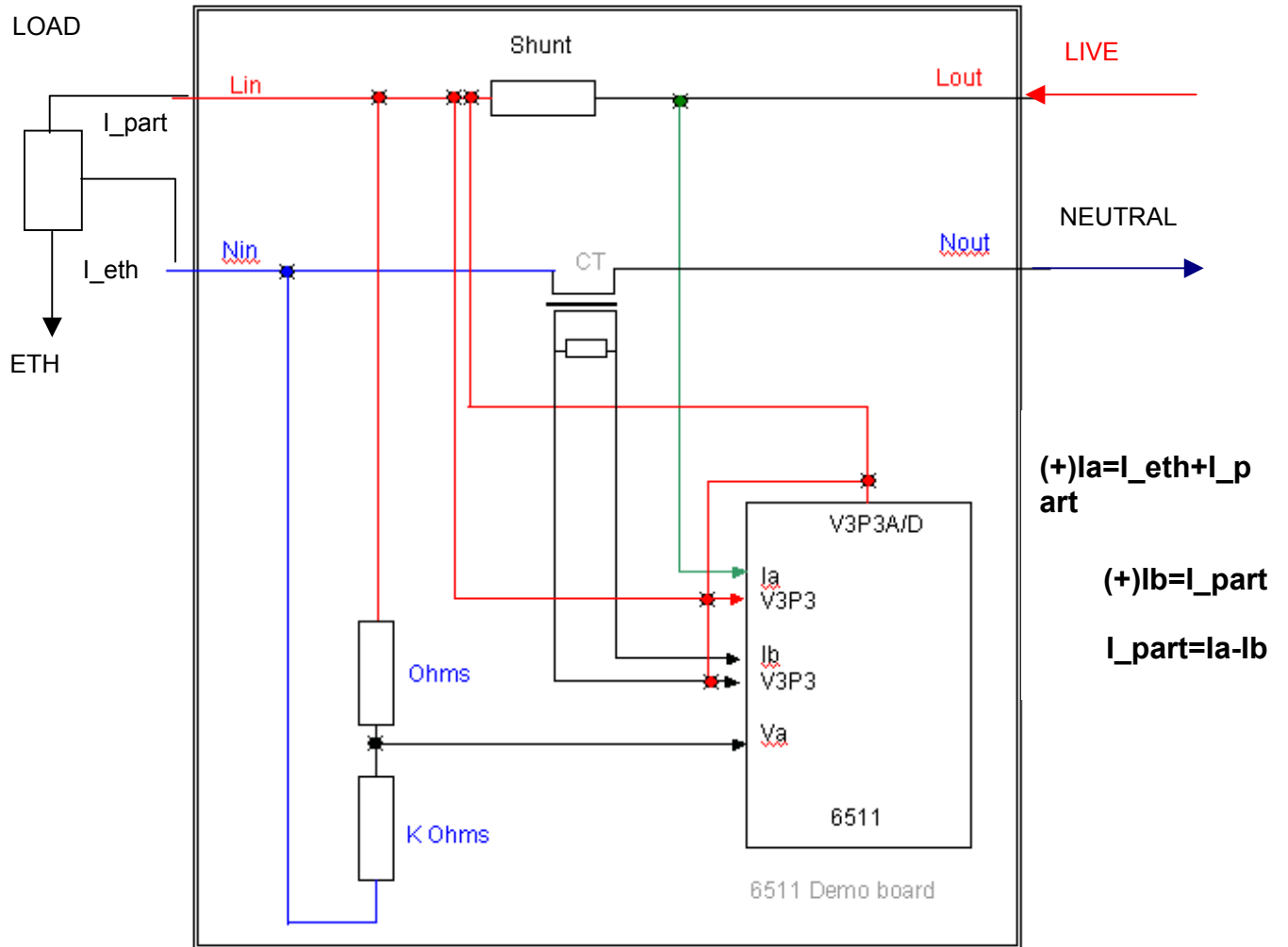


Figure 13: Tamper method #12, I/O swapped. Load partially connected to ETH (Nin=Nout).

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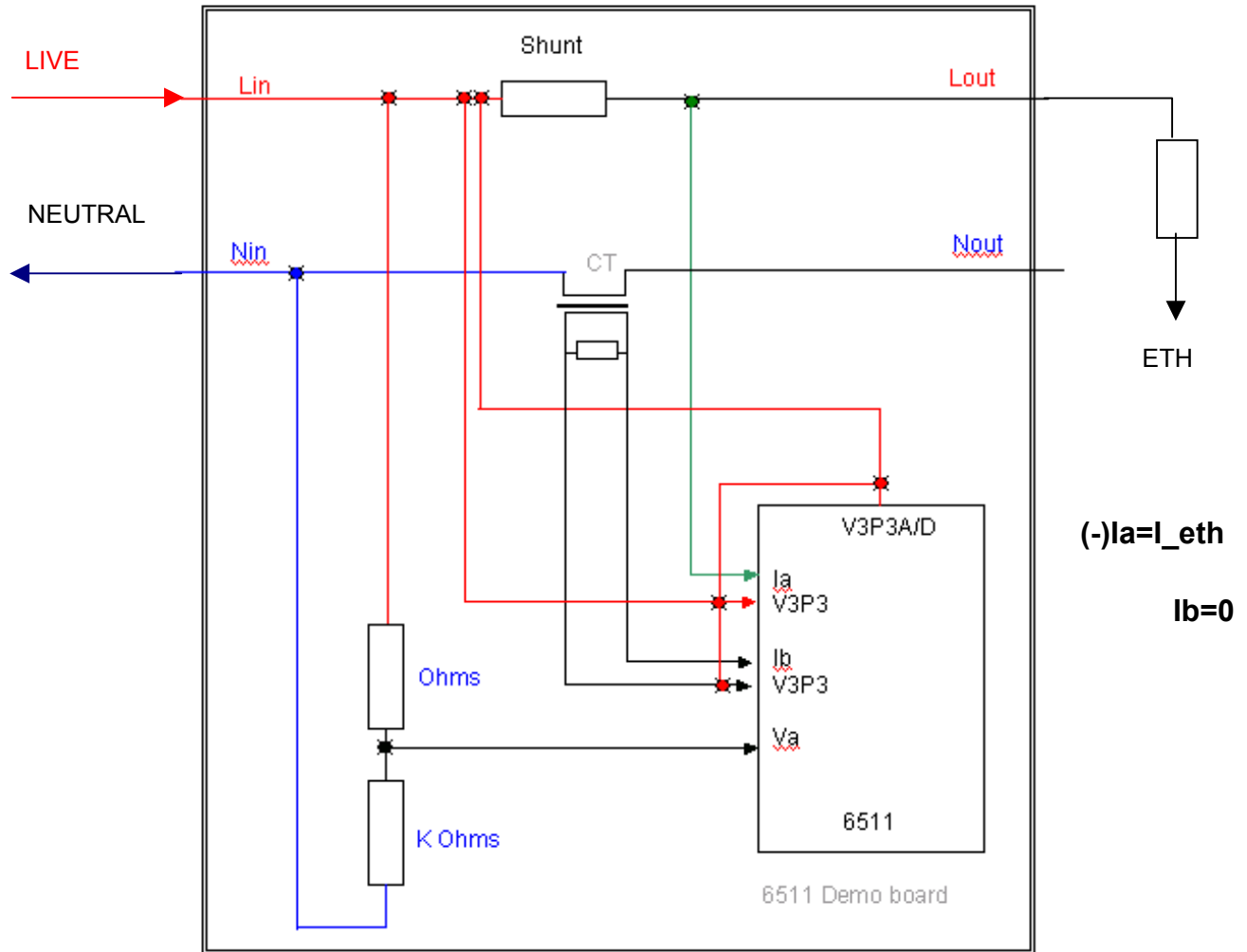


Figure 14: Tamper method #13, Load connected to ETH.

6511 Calibration for Shunt and CT

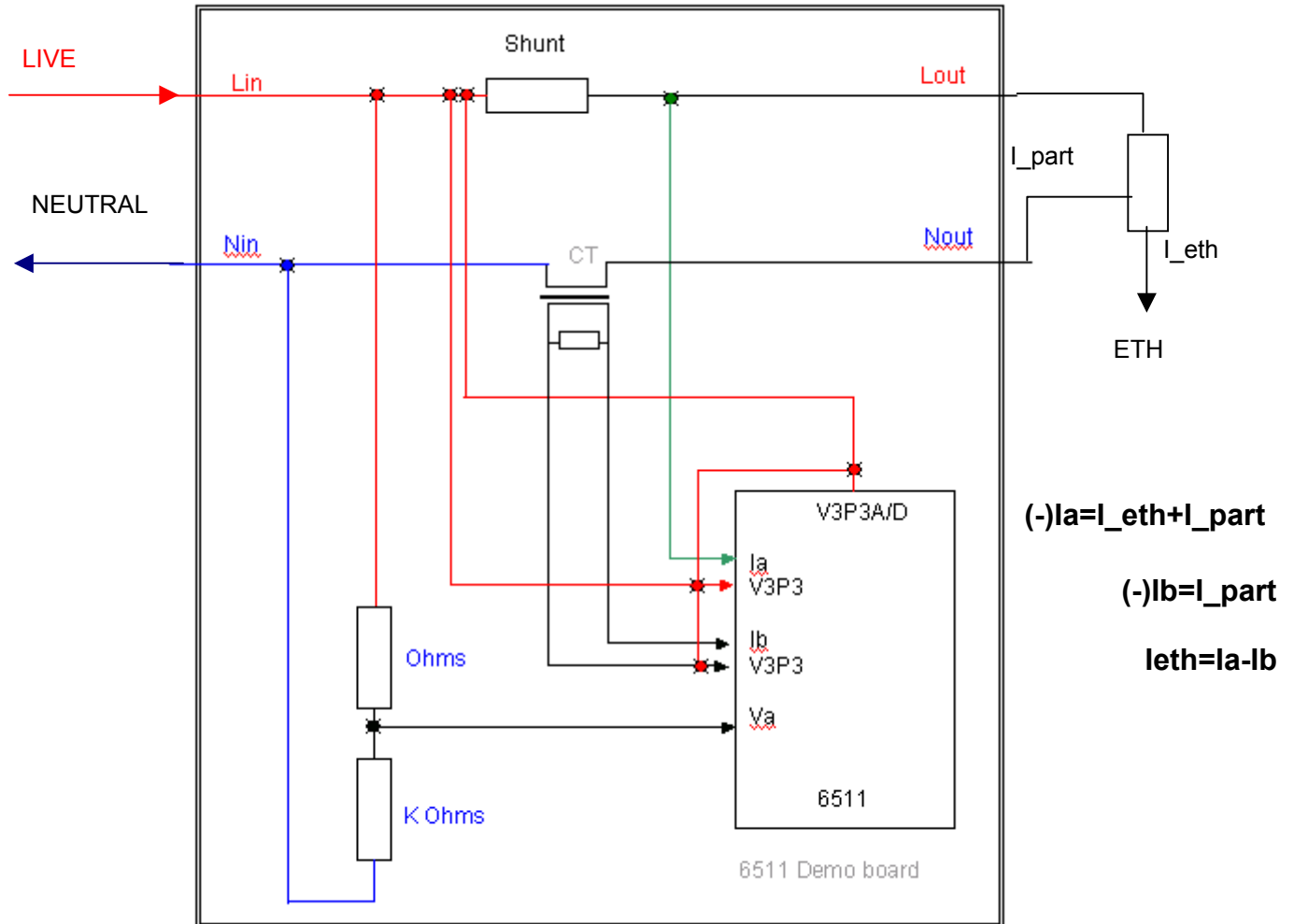


Figure 15: Tamper method #14, Load partially connected to ETH.



**TERIDIAN 71M651x
Power Meter IC**

6511 Calibration for Shunt and CT

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