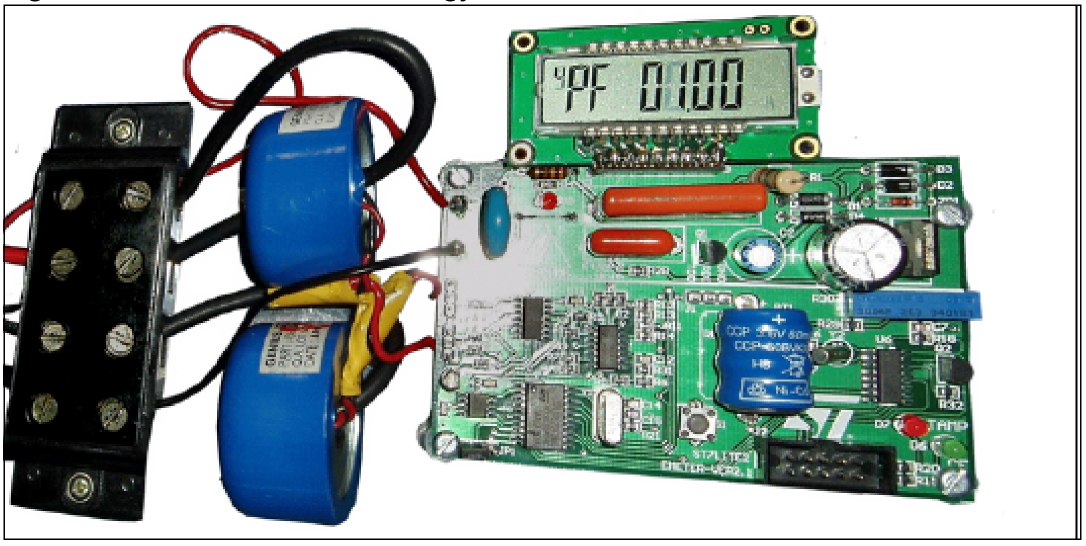
Calibration procedure for STEVAL-IPE007V1 single-phase energy meter based on ST7FLite2x

Introduction

This application note describes the calibration procedure for STEVAL-IPE007V1, a single-phase power / energy meter with tamper detection.

Calibration is performed to minimize measurement errors and to increase the accuracy of the meter.

Figure 1. STEVAL-IPE007V1 energy meter



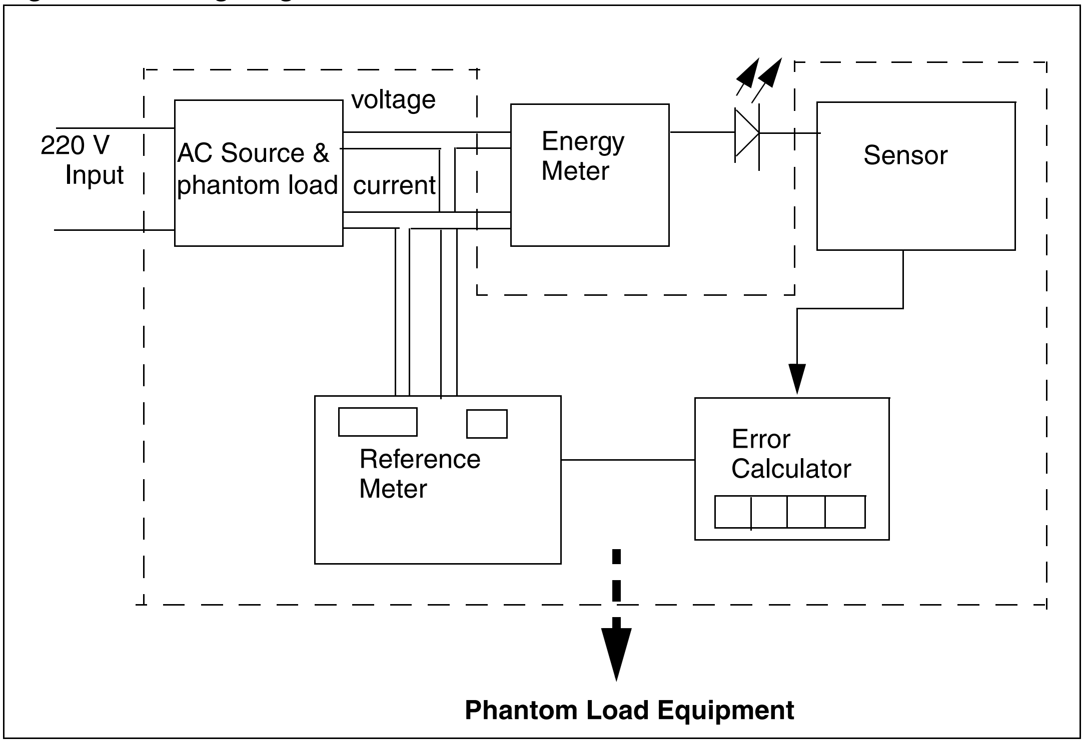
Contents

1 Calibration procedure

The procedure for meter calibration is explained below by firstly giving an overview of the hardware set-up, and then by describing how to connect a calibration board and energy meter GUI to update the firmware of the board.

1.1 Hardware set-up

Figure 2. Wiring Diagram_



- **AC Source and Phantom Load:** As shown in *Figure 2*, this provides the AC source and serves as a virtual load providing the current and voltage ratings as per the circuit requirements.
- **Energy Meter:** The required voltage and current of the energy meter input is provided by the phantom load. The basic current of this meter is 10 A with a maximum current rating is 50 A. Operating voltage is 140 to 280 V.

  As can be seen in the block diagram, there is an LED called the pulse count LED drawn at the output of the meter. It glows at the rate of 3200 imp/kWh.
- **Sensor:** The sensor detects the current pulses of the pulse count LED and thereby shows the error on the error calculator screen. As can be seen from the block diagram, the sensor is connected to the error calculator.
- **Reference Meter:** This acts as a reference to the various measurements made with the energy meter. The meter constant and the pulse count can be set with the help of the reference meter. The meter constant is initially set to 3200 imp/kWh and the pulse count is set according to the current at which the error is to be measured. For example,

if the pulse count is set to 15, this means that after 15 current pulses, the error calculator shows the deviation of the energy meter from the reference meter.

- **Error Calculator:** As the name suggests, this calculates the error and shows the value on its screen. The Error is the deviation of the energy meter from the reference meter.

1.2 Calibration

There are two methods of meter calibration

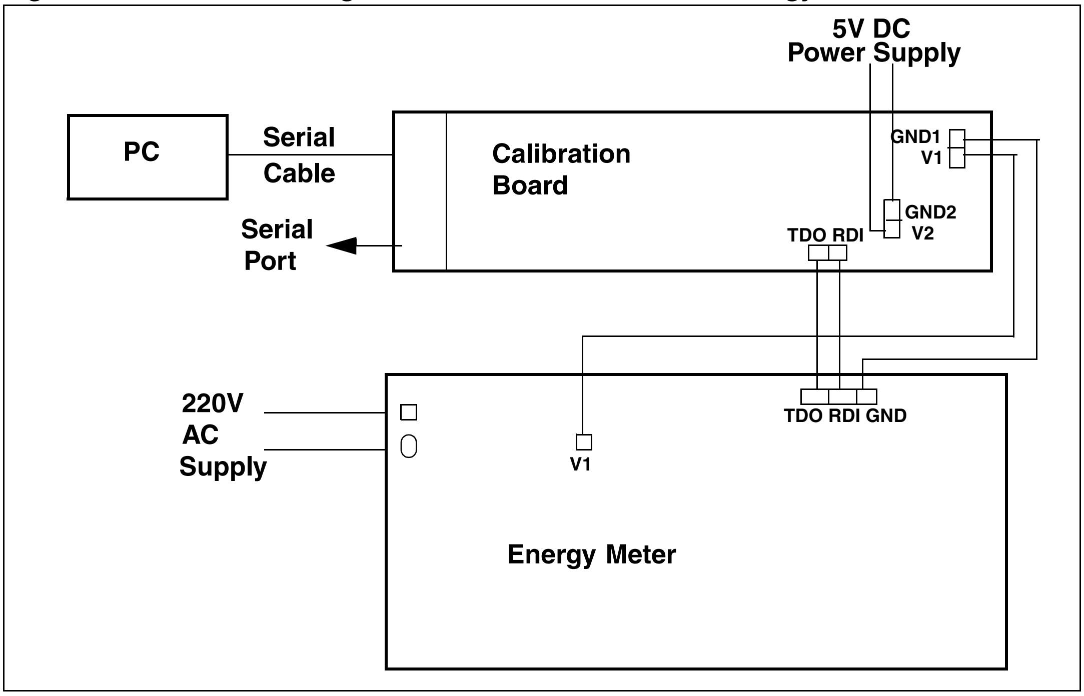
- **Using Firmware:** This uses firmware and a calibration board linked to a PC, and through the use of an Energy Meter GUI, calibrates the Energy Meter board. Before doing this, the micro should have code inside. Refer to *Section 1.2.1 on page 4*.
- **Using Energy Meter GUI:** This method uses only a calibration board linked to a PC and through the use of an Energy Meter GUI, calibrates the Energy Meter board. Before doing this, the micro should have code inside. Refer to *Section 1.2.2 on page 7*.

1.2.1 Using firmware

Here, the firmware is used for calibration of the energy meter. The various steps to follow are as follows:

1. First of all, the energy meter calibration board is connected with the PC Energy Meter GUI using a serial cable. Then, the energy meter calibration board must be connected to the meter. The connection diagram of the calibration board with the energy meter and the PC is shown in *Figure 3* below:

Figure 3. Connection diagram of calibration board with energy meter and PC

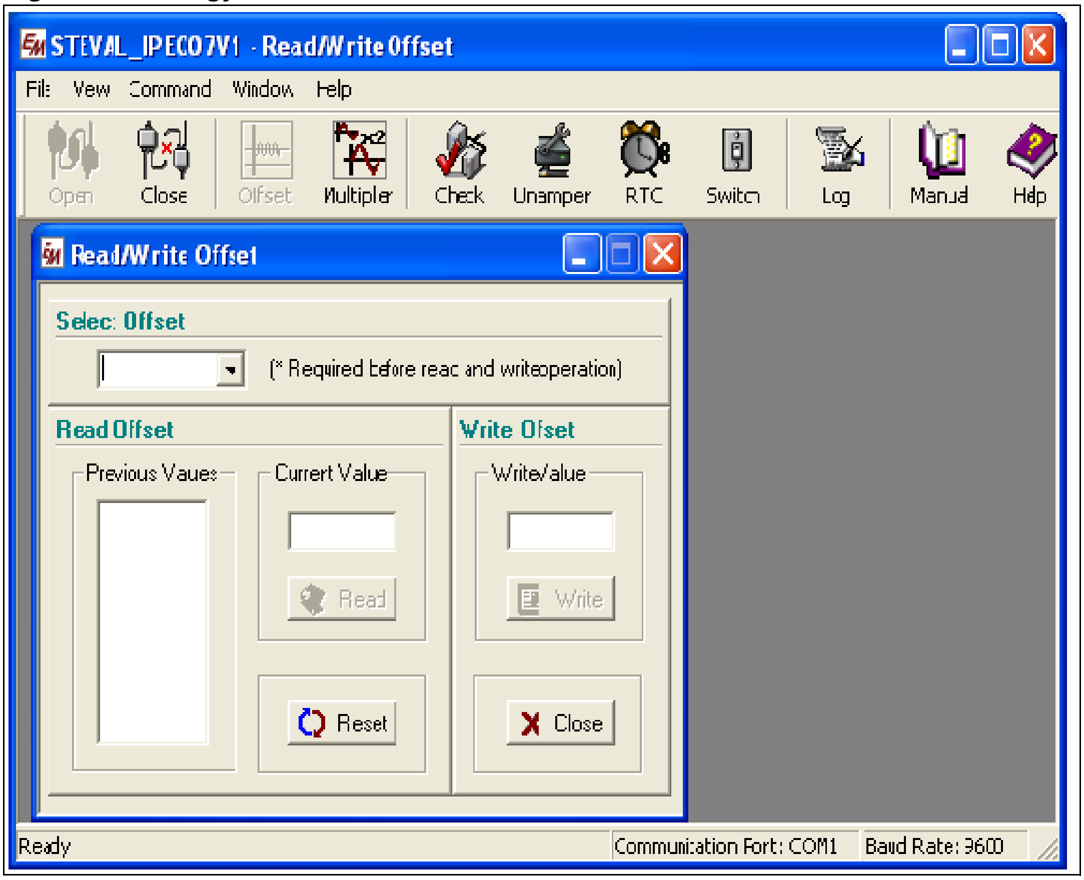


2. A 5V DC supply should be connected to the GND2 and V2 pins of the calibration board. For the calibration mode, a switch is provided on the energy meter which must be

pressed within 30 seconds of the supply of power to the unit. The energy meter then switches into **calibration mode**.

3. Then, on the PC, it is necessary to open the **Energy Meter GUI V1.x.x**. This shown in *Figure 4* below:

Figure 4. Energy meter GUI



To operate the Energy Meter GUI:

4. First press **Open**, a window appears in which the baud rate should be selected as 9600 and COM port as COM1. Then, press the calibration switch on the energy meter and click on the **Check** icon (upper middle), shown in *Figure 4*. With successful communication, the message ‘Device is connected’ appears and voltage/current offsets can be read. Otherwise, check the connections between the energy meter/calibration board/PC and repeat the earlier steps.

5. The voltage/current offsets can now be read:

   a) First, read the voltage offset. To do this, click on **Offset icon** (right side of close icon). On the window that appears, click on the **Select** icon. Four gain multipliers and a 220V reading are displayed. To read the voltage offset, click on 220V.

   Press the calibration switch of the energy meter again and click on the **Read** icon (bottom left) of the GUI. Offset values appear in the “Previous Values” column (bottom left) as shown in *Figure 4*. Select a value that appears most frequently. This value is to be taken as the voltage offset.

b) Now read the current offsets at 0.5A, 2A, 8A, 32A in the same manner as described above. Here, select the gain multipliers for reading the offsets as shown in *Table 1* below:

Table 1. Gain multipliers used when reading current offsets

Current Ratings	Gain Multipliers
0.5A	X128
2A	X32
8A	X8
32A	X2

6. After taking offsets, enter these values into the *init_EEPROM[ ]* array which is used in the firmware.

   For example, if the offset obtained for 0.5A is 02FF, then the user has to enter this in the following manner:

   0x02,0xFF and the location where the user has to write the offset is shown in *Table 2* below:

Table 2. Byte locations used when entering the offset values

Current Ratings	Byte location in *init_EEPROM[ ]* array
0.5A	12th and 13th byte
2A	10th and 11th byte
8A	8th and 9th byte
32A	6th and 7th byte
220V	14th and 15th byte

   The first byte of this array must also be changed to make the calibrated offset values effective.

7. Now compile the code and update the firmware in the microcontroller.
8. After doing this, the error must be checked at 32A, 8A, 2A and 0.5A.

   This is done by connecting the energy meter to the AC mains and the reference meter. The goal is to minimize the error for each current rating.

   The procedure for doing this is given below:

   – Each current value mentioned above has a pre-stored calibration constant in the *init_EEPROM[ ]* array. Their locations are shown in *Table 3* below:

Table 3. Pre-stored calibration constant byte locations

Current Ratings	Byte location in *init_EEPROM[ ]* array
0.5A	28th-31st
2A	24th-27th
8A	20th-23rd
32A	16th-19th

   – The pre-stored bytes have to be grouped together for the corresponding current rating.

For example, for 0.5 A, we have the following four bytes in *init_EEPROM[ ]* array.

0x23, 0x45, 0xFD, 0xAE

These are written as follows: 0x2345FDAE.

– Similarly, the bytes for the other three current values should be grouped. These pre-stored calibration constants should be modified according to the errors obtained for each current value. The procedure for doing this is explained with the help of an example.

  Suppose the error is +*x*% for the calibration constant of 2345FDAE, for example, 0.5A.

– First, 2345FDAE should be changed to a decimal value.

  The decimal value for this is 591789486.

– Now, add the error to it as shown: 591789486 + (591789486 * *x*%)

  That is, 591789486 (1 + *x*%).

– After this, the final value obtained should be changed back to its hexadecimal equivalent.

– Now, if the error is -*x*%, then we have to only change the sign as shown below:

  591789486 (1 - *x*%).

– The value finally obtained should again be changed to hexadecimal format.

  We have perform the above procedure for all the four values of current.

– After doing this, we have to write the corrected calibration constants at their respective locations in the *init_EEPROM[ ]* array as shown above in *Table 2*.

This completes the procedure for minimizing the errors for meter calibration.

9. Finally, the first byte value of *init_EEPROM[ ]* has to be changed in order to make the modified information effective. Following a compile operation, the firmware in the microcontroller can be updated.

This completes the calibration procedure.

1.2.2 Using the energy meter-GUI

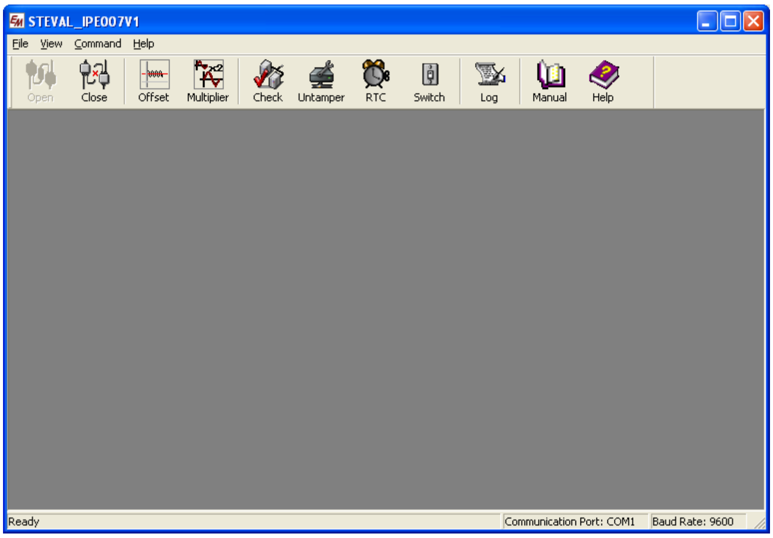
The second method for meter calibration is using the energy meter GUI.

In addition to calibration, other tasks can performed with the PC-GUI such as untampering the meter, setting the RTC and switching the meter in the calibration mode.

Functional description

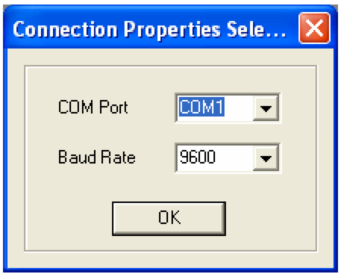
The functional description of the PC-GUI is given below.

Figure 5. Energy meter GUI



1. **Open:** This selects the connection properties. When clicked (upper left corner), a window appears as shown below.

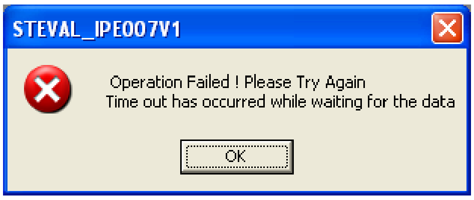
Figure 6. Connection properties window



As shown in the figure the COM port is selected as COM1 and baud rate is 9600.

2. **Check:** The check icon makes sure that the meter is connected with the calibration board. If connected, the message 'Meter is connected' appears when the check icon is clicked. Otherwise a warning message is displayed as shown in the figure below.

Figure 7. Window showing that the meter is not connected



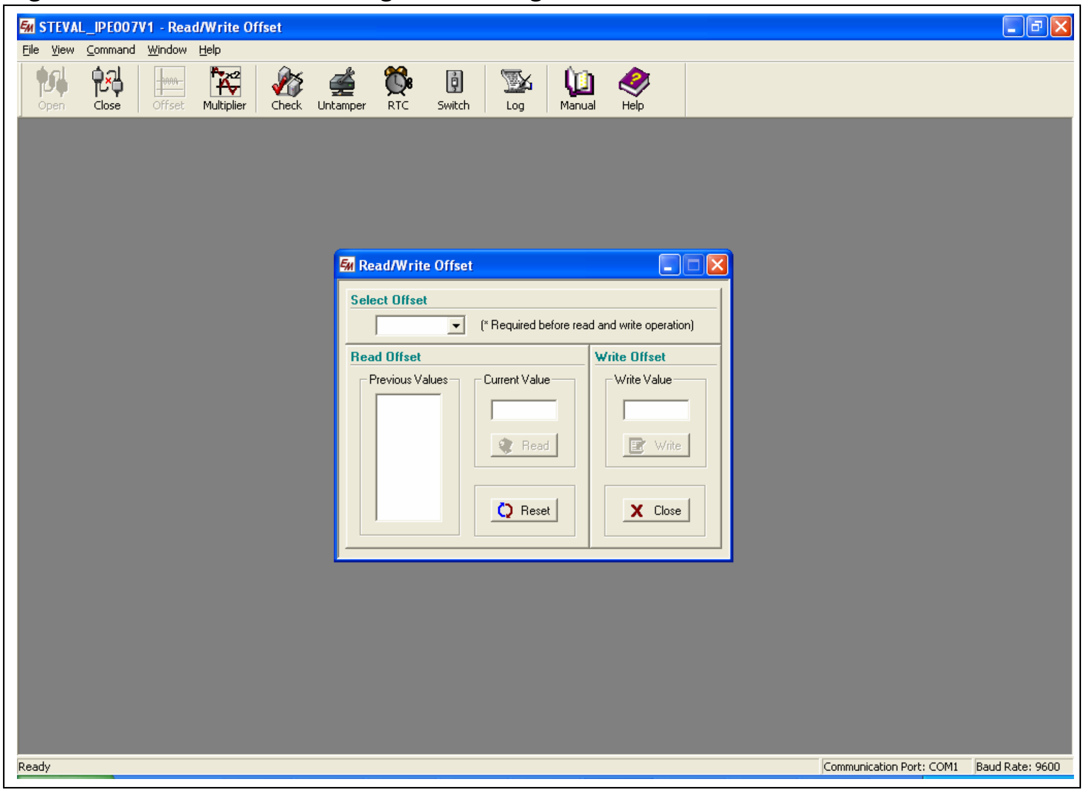
Click **OK**, check the connection, and try again by clicking on the check icon.

Read/write offsets

Once the meter is connected, the offsets should be read and written to EEPROM.

- Click on the **Offset** icon (upper left on the task bar). A window as shown in figure below appears.

Figure 8. Window for reading and writing of offsets



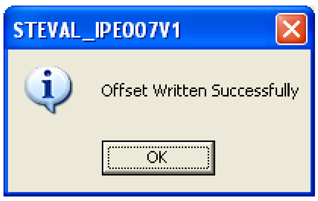
- Four current offsets are available, X128, X32, X8, X2, and one voltage offset for 220V. Select the required offset from the **Select Offset** dropdown box as shown in *Figure 8*. Corresponding to the selected offset for current, the load current on the phantom load equipment should be adjusted. Voltage offset is independent of the current value.

Table 4. Current values corresponding to the offsets

Gain Multiplier	Current value
X128	0.5A
X32	2A
X8	8A
X2	32A

- Click on the **Read** icon to read the value for a particular offset. After reading a set of values, click on the **Write** icon. If the write operation was successful, the message shown in *Figure 9* is displayed.

Figure 9. Window showing that the offsets have been written successfully



The above procedure should be repeated for each of the five offsets.

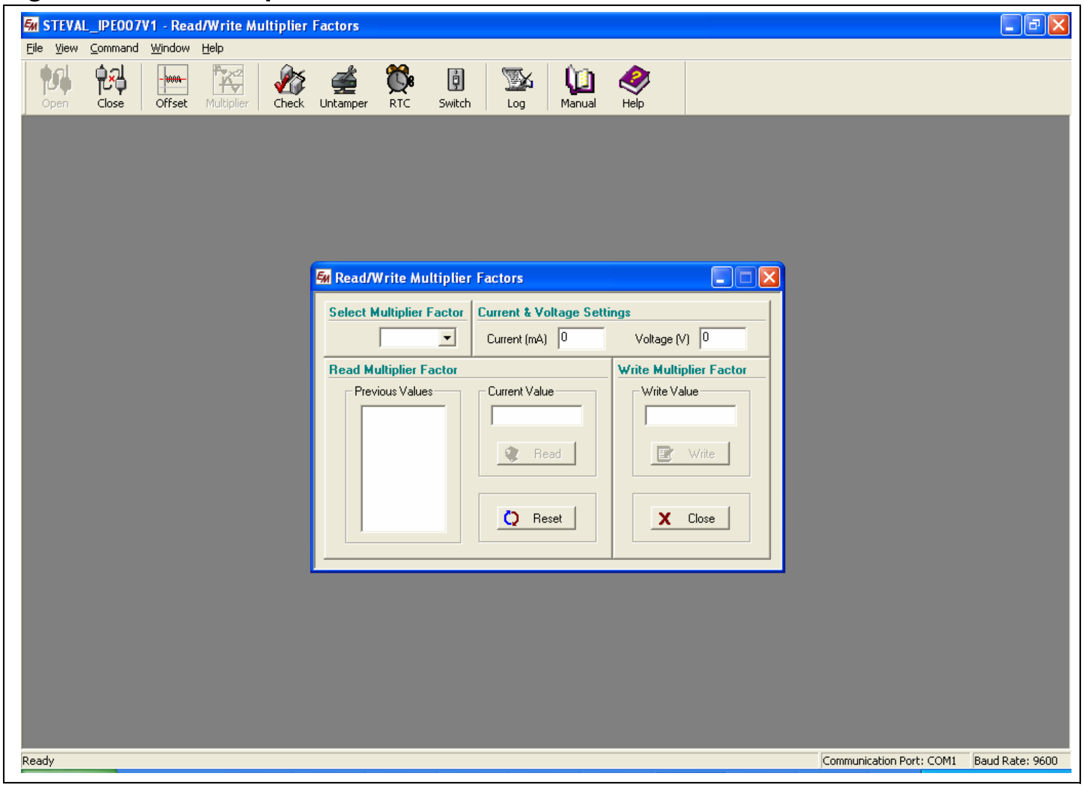
This completes the procedure for reading and writing the offsets.

Read/write multiplier factors

The next step of reading and writing the multiplier factors reduces the error percentage.

- Click on the multiplier icon (upper left on the task bar), a multiplier window appears as shown in figure below.

Figure 10. The multiplier window



Each multiplier factor corresponds to a range of current. This is shown in the table below:

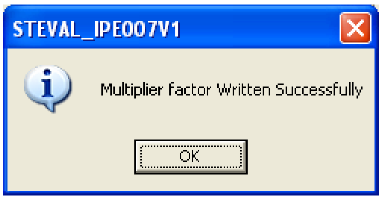
Table 5. Gain multipliers and the corresponding current range

Multiplier factor	Current range
X128	0A -> 0.9A
X32	0.9A -> 3.6A
X8	3.6A -> 13.5A
X 2	13.5A -> 60A

- According to the selected multiplier factor, the corresponding current (in mA) and voltage (V) should be entered in the provided spaces, in the upper-right corner of the multiplier window, as shown in *Figure 10*. These values are those provided by the phantom load equipment and are also shown in *Table 5* above.

One multiplier factor should be taken at a time. Read the offsets by clicking on the **Read** icon. After taking a set of readings, click on the **Write** icon. After a successful write operation, message appears as shown in *Figure 11*.

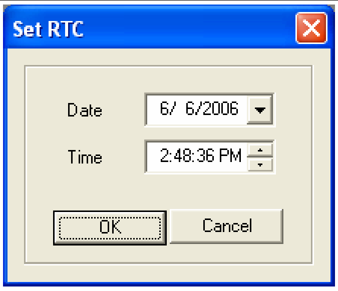
Figure 11. Window showing that the multiplier factors have been written successfully



This procedure should be repeated for each of the four offsets.

3. **Untamper:** As the name suggests, this untampers the energy meter from its current tampered state. A message saying 'Meter successfully untampered' appears on the screen.
4. **RTC (Real Time Clock):** This is used for setting the current date and time. Click on the RTC icon, and a window appears as shown in *Figure 12* below:

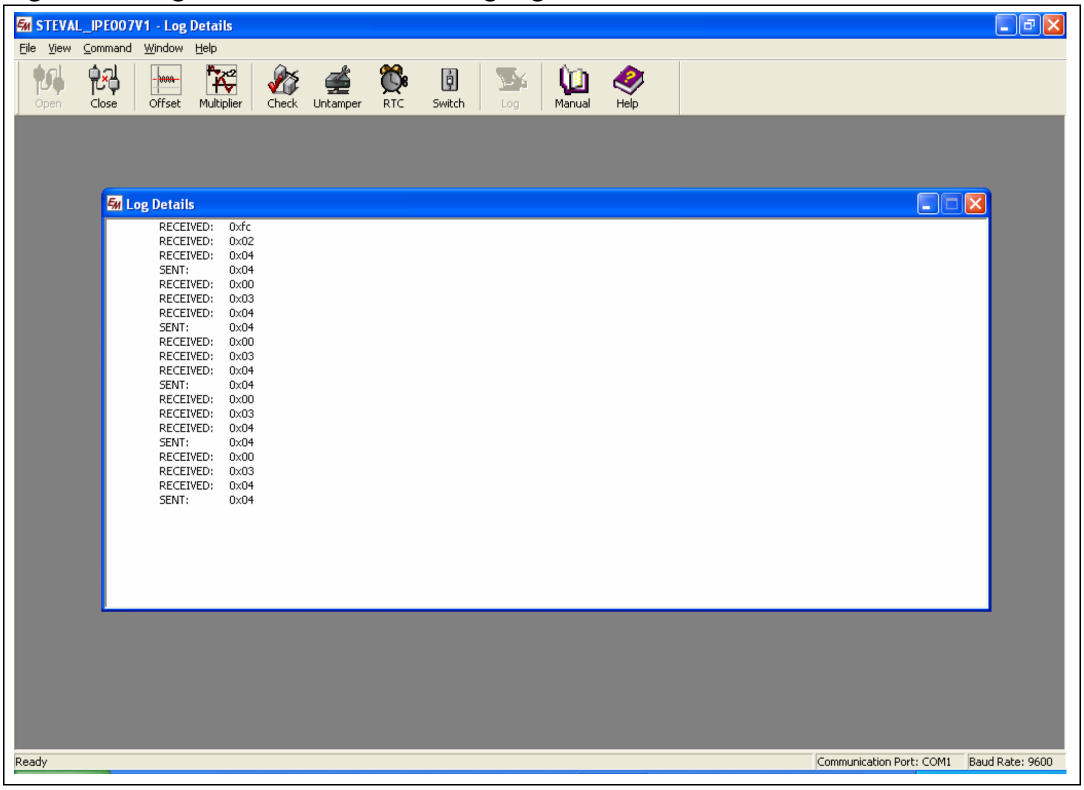
Figure 12. Window to set current date and time



This window always shows the current date and time. Click **OK** and the meter is calibrated with the correct date and time. A message saying 'RTC set successfully' appears on the screen.

5. **Switch:** Once clicked, the meter shifts to the normal mode of operation from its current calibration mode. A message saying 'Electricity meter is switched to normal working mode' appears.
6. **Log:** Log file gives the details of the bytes sent and received. It is as shown in figure below:

Figure 13. Figure 10: Window showing log details



When the user closes the log file, an option comes for saving the file. The user can save it to the desired location.

2 Revision history

Table 6. Document revision history

Date	Revision	Changes
06-Apr-2006	1	Initial release.
18-Jul-2006	2	Addition of *Section 1.2.2: Using the energy meter-GUI on page 7* Title of document modified to encompass non-firmware method of calibration now described