CleverLoad Initialization & Calibration

What This Program Does

CleverLoad requires EEPROM data to be populated before it can operate properly. The RF measurement subsystem will operate without calibration but will provide more precise RF power measurements after calibration. The unit also contains a real time clock used to time stamp dataloged data and it's also used as a timer to turn the unit off after a user selected period of inactivity.

This Initialization and calibration program provides facilities for the following tasks:

1. Set the real time clock
2. Trim the clock's oscillator using the ISL12026 ATR and DTR registers to optimize clock accuracy
3. Calibrate the RF measurement system's:
    a. 0dBm reference value
    b. Peaking gain scaling factor
    c. High power scaling factor
4. Review & record calibration data generated
5. Write EEPROM
6. Turn the unit off

Background

CleverLoad contains an Intersil ISL12026 real time clock with EEPROM, an Analog Devices AD8362 RF detector, a PICAXE 20X2 micro processor and other devices.

The real time clock is used for data logging and timer housekeeping. The EEPROM is used to hold housekeeping data as well as an anti-log table for dBm to Watts conversion, display character generator special characters for bargraph and battery symbols, and backlight level set data.

RF calibration is central to this device. The CleverLoad application uses 0dBm as a key calibration point and all absolute power measurements are referenced to this value. As power increases from 0dBm errors are introduced, but to a first order these can be corrected in software. Errors result from non-ideal AD8362 detector output, A-D nonlinearities and A-D reference voltage inaccuracy. The AD8362 output is typically 50mV/dB but this can vary by +/- 4mV per dB. Added to this are A-D converter errors and errors in the absolute value of the MPC1541 4.096V reference device which is used as the positive reference for the A-D converter. These errors are all typically stable and systematic so can be compensated in software. To do this an accurately known high power reading, between 30 and 40dBm is recorded and the calibration program calculates a scaling factor based on the reading from the A-D converter and the actual RF power value entered by the user. The high power scaling factor subroutine automatically generates this scaling factor. The CleverLoad application then applies it in calculating all power readings above 0dBm.

This software also automatically generates a peaking mode scaling factor. The peaking mode provides a +/-3dB measurement 'window' on the display that features a bargraph and digital readouts of both the absolute power in dBm to a tenth of a dB and a relative dBr reading with a .01dB resolution. The bargraph resolution is .075dB per element. To achieve this resolution an internal 8x amplifier is used to generate a signal to one of the PICEXE A-D converter inputs. With this gain a one bit change on the ten bit converter represents a .01dB power change. Over the three dB 'Peaking Mode' window the converter changes 300 counts. The peaking mode scaling factor accounts for gain inaccuracies in the amplifier, scaling the output to exactly 300 counts for a 3dB change in RF input level. The 'Peaking Cal' subroutine automatically calculates and stores the SfP scaling factor for peaking.

The calibration procedure will generate five calibration parameters:

ATR – the real time clock Analog Trim Register accurately sets the crystal fine frequency
DTR – the real time clock Digital Trim Register can be used for crystal fine adjustments
0dBm – The keystone reference power measurement. The precision of all CleverLoad power measurements depends on the accuracy of this value.

Sf – high power scaling factor improves accuracy of high power readings especially in the range above 30dBm.

SfP – Peaking scaling factor increases accuracy of +/- 3dB peaking measurements.

These five parameters are automatically stored in EEPROM by the program as each calibration section is completed. They can also be reviewed by using the 'Show Cal Data' menu item.

CleverLoad will perform well without calibration and should be able to provide power level readings within 1dB using the default data. Any of the five calibration parameters can be performed individually at any time although it is best to do the '0dBm' and 'Hi Power Cal' as a pair. The most important parameter is the '0dBm Cal' as it provides the reference for all other power measurements. That is if the 0dBm reading is in error by +0.75dB, all other readings will have this error plus any additional scaling errors as power is increased from 0dBm.

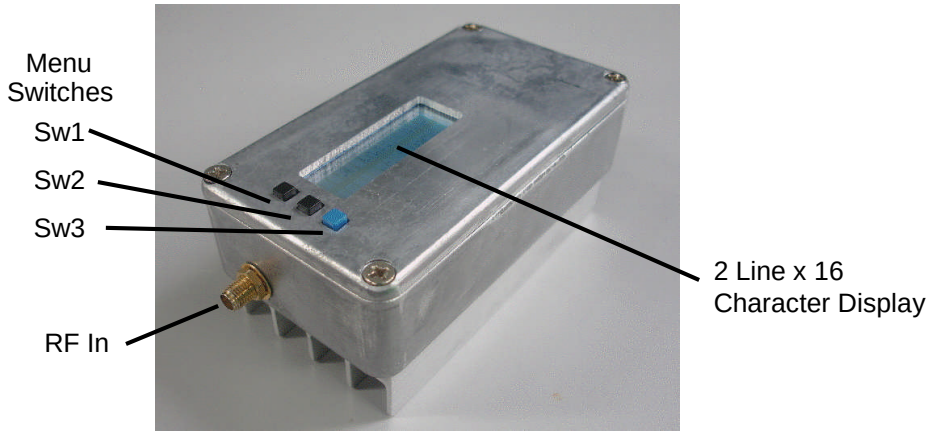
Clock calibration isn't necessary unless precise time stamps are required for data logging. However CleverLoad will show accumulated errors in the time displayed resulting from crystal frequency error.

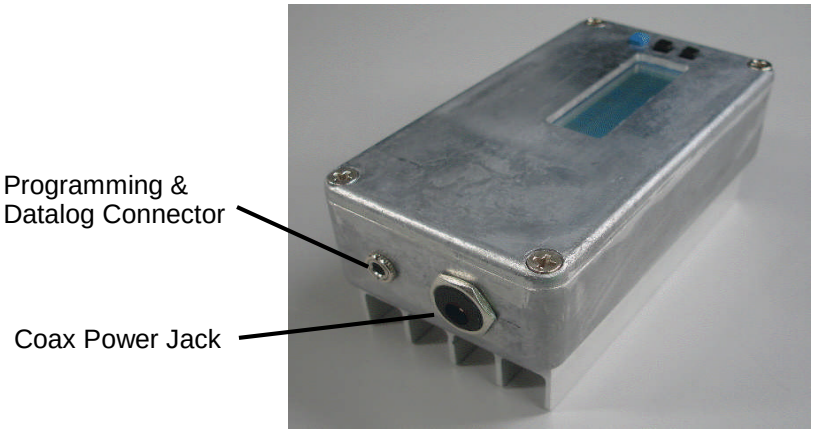
While CleverLoad calibration isn't absolutely necessary it is essential that the EEPROM be written to provide default calibration parameters as well as other data CleverLoad requires to run properly. As a minimum, run the 'Write EEPROM' subroutine. Running the 'Set Clock' is also a useful and easy task to do be done before using CleverLoad.

CleverLoad Overview

Switch Layout & Connections

CleverLoad has only a few I/O ports and controls as outlined in the pictures below.





Menu Navigation

CleverLoad uses the three switches to the left of the display to navigate through and select menu items.

Up and Dn appear on the display next to Sw1 and Sw2 in the main and submenus. Pressing either button will move up or down to the next menu item. If at the top of the menu, Up will not appear, and if at the bottom, Dn will not appear as an option. Menus are navigated using the Up Dn buttons and menu item are selected by pressing Sw3. The same procedure is used with submenu items.

The calibration software contains the following menus.

Main Menu items have the 'SL Utilities' title displayed on line 1 and will show the following menu options on line 2

Set Clock - Sets real time clock Year, Month, Day, Hour, & Minute
Clk Cal Freq - Trims the clock oscillator to 32768Hz using ATR & DTR registers
RF Power Cal - Sets 0dBm, & scaling factors for Peaking and High Power
Show Cal Data - Displays the five cal parameters ATR, DTR, 0dBm, Sf & SpF
Write EEPROM - Writes cal data, special display characters, housekeeping data & antilog table data to the EEPROM data
Turn Unit Off - Does exactly that

'Set Clock', 'Clk Cal Freq' and 'RF Power Cal' have submenu items that are described in detail in each calibration section.

If you accidentally navigate to and enter the wrong menu item pressing S3 again will return you to the main menu. In submenus the last menu item in submenus is a return to the main menu. Navigate to this item then select it by pressing S3 to return to the main menu. Typically when exiting a submenu the main menu will be indexed and display the next menu item.

Initialization & Calibration Procedure

Equipment You'll Need to Perform the Calibration

To calibrate CleverLoad and improve accuracy to better than 0.25dB the following is needed:

1. A computer with the Picaxe Programming Editor installed
2. The CleverLoad calibration software
3. A Counter with ten or preferably one miliHertz resolution to accurately set the 32,768Hz clock oscillator
4. A RF signal generator capable of providing a minimum +10dBm output at 50MHz with
    a. A 0dBm known accuracy to 0.1dB at 50MHz. for the zero dBm reference point
    b. A 3dB attenuator accurate to 0.1dB or better or an adjustable attenuator on the signal generator output with the same precision to calibrate peaking mode.
5. A high power RF source at 50MHz providing between 30 and 40dBm with a known accuracy to 0.1dB

Download the CleverLoad Calibration Software

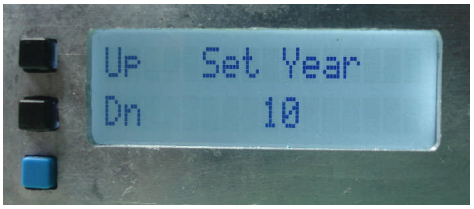
To do this follow the process outlined in the 'How to Download a Program to CleverLoad' section.

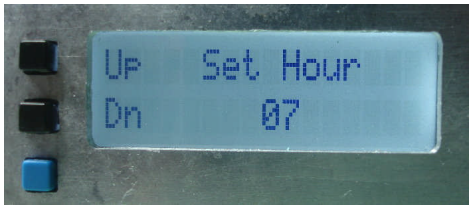
Set the ISL12026 clock

1. Navigate to the 'Set Clock' menu item in the 'SL Utilities' main menu. This is the first menu item.

2. Press Sw3.
3. This will take you to the next screen which displays the time in HH:MM:SS in 24 hour format on the top line and DD/MM/YYYY on line two. There is also a <-Set option opposite Sw2.

4. If the time and date data don't need changing press Sw3 to go back to the main menu. Otherwise press Sw2 to enter the clock set menus.
5. The clock set menus will present you with the following items year, month, day, hour, and minute.





6. Press the Up or Dn buttons to change the value for each screen then push Sw3 to accept the new value and advance to the next screen

7. The 'Set Min' screen operates the same way as the others except that when Sw3 is pushed the minutes indicated and 00 seconds are written to the clock. So when setting the minutes, advance the setting to the next minute, wait until 00 seconds then press Sw3. When Sw3 is pressed the program will exit the clock set subroutine and advance the next main menu item.

Set the ISL12026 clock Analogue and Digital trim registers

1. Remove the top cover from CleverLoad and locate the clock oscillator test point
2. Attach a high impedance probe from the counter to the test point.
3. Navigate to the 'Clk Cal Freq' menu item and press Sw3

ATR Analog Trim

4. Navigate to the 'Analog Trim' submenu and press Sw3

5. While monitoring the frequency counter increase or decrease the ATR capacitance by pressing the Up or Dn buttons so that the counter reads as close to 32,768.000 Hz as possible.

6. When the reading is as close to 32,768 as possible, press Sw3. This will save the reading in EEPROM and send you to the next 'Trim Xtal Cap' menu item Digital Trim.

DTR Digital Trim

1. After exiting the Analog Trim menu the program should place you at the 'Digital Trim' menu. If not navigate to it and select it by pressing Sw3.

2. In the Dig Freq Trim submenu press the Chg button while monitoring the crystal frequency and select the value that places the frequency as close to 32,768.000Hz as possible .

3. Exit the digital trim submenu by pressing Sw3. This will save the reading in EEPROM and increment to the next submenu item 'Return to Main Menu'. Press Sw3 to do so.

Calibrate the RF measurement Subsystem

Navigate to the 'RF Power Cal' submenu and press Sw3

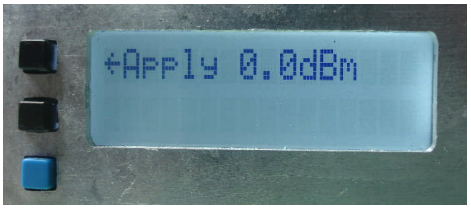
0dBm Cal

This procedure measures and stores a 0dBm reference count which is used as the base for all power measurements. The value is read from the RF detector output at the PICEXE A-D converter input and is stored as the 0dBmRef value during this procedure.

The '0dBm Cal' should be the first submenu item in the RF Power Cal menu, if not press the Up & Dn buttons to navigate to the '0dBm Cal' menu.

Apply 0.0dBm from the signal generator.

Press Sw3. When the '<- Apply 0.0dBm' screen appears press Sw1.



The program will return the value to be stored for 0dBm

This value is the raw PICAXE A-D count measured from the AD8362 detector output. It should typically be between 210 and 214.

Press Sw3 to save the value and continue with the calibration.

Peaking Cal

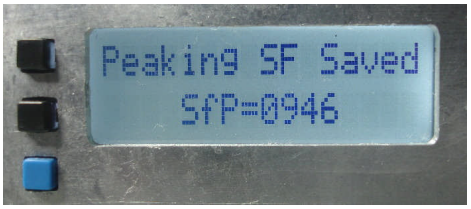
This procedure creates a scaling factor to increase the accuracy of the 3dB peaking gain measurements.

1. Navigate the calibration menu selecting the 'RF Power Cal' then 'Peaking Cal' menu.

2. Press Sw3 to enter the Pealing Cal subroutine
3. Apply a +7.00dBm CW signal at 50MHz to CleverLoad.

4. Press Sw1. The display will show a ‘Stabilizing’ screen followed by an Apply +10.00dBm screen

5. Apply +10dBm and press Sw1. The unit will again display a ‘Stabilizing…’ screen followed by a calculated result that shows the scaling factor SfP stored for this parameter. The scaling factor will typically be around 950. It should range between 925 and 975 and should never be above 1000. If the result is outside the range check the applied power levels and redo this measurement.



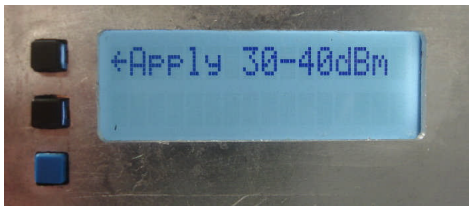
6. Press Sw3 to save the scaling factor and exit this section.

Hi Power Cal

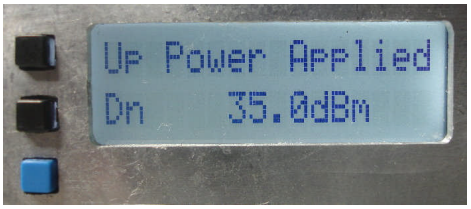
This procedure creates a scaling factor to account for small errors in the measurement system as the power level increases from 0dBm to +50dBm.

1. Navigate to the CleverLoad Calibration menu selecting ‘RF Power Cal’ then the ‘Hi Power Cal’ sub menu and press Sw3 to enter this routine.

2. Apply a 50Mhz RF signal at between 30.0 and 40.0dBm then Press S1



3. The program will now ask you to enter the value of the power applied. It will initially display 35.0dBm. Use the Up Dn buttons to change the display to the actual power applied. Then press Sw3.



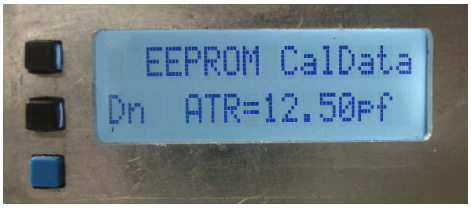
4. The cal program will calculate, save, and then show the calculated scale factor Sf. It should typically be 800 and range between 775 and 825. If the result is outside the range check the applied power levels and redo this measurement.

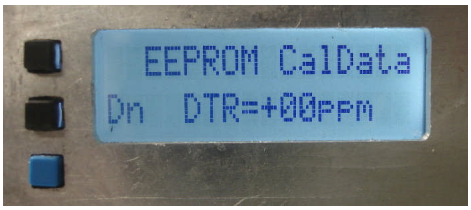
5. Press Sw3 to exit this section

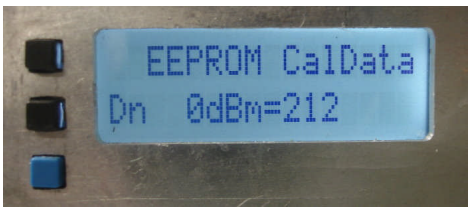
Review and Record the Calibration Data

This subroutine displays the contents of the five calibration values, Clock ATR Clock DTR, 0dBm value, Hi Power Scale Factor, and Peaking Mode Scale Factor presently stored in the unit.
To view the data

1. Navigate to the 'Show Cal Data' then push Sw3.
2. Press the Dn button to scroll though the stored calibration data. The display will start with ATR, then DTR, 0dBm, Sf, SfP, then loop as the Dn button is pressed.







Exit this subroutine by pressing Sw3 at any time.
The user should save this data by modifying the CleverLoad Calibration program just in case the EEPROM data becomes corrupt. Should this happen, CleverLoad calibration data can be restored without recalibrating the device.

To save this data load the CleverLoad Calibration program into the PICEXE Programming Editor. Go to about line 850 in the program, the section labeled 'RECORD CALIBRATION DATA FROM 'SHOW CAL DATA' SUBROUTINE IN THIS SECTION'. Modify the calibration parameters to match those in the Show Cal Data display. Do NOT uncomment any lines.
Now save this modified program as your default CleverLoad Calibration program to be loaded anytime you need it in the future. To do this:

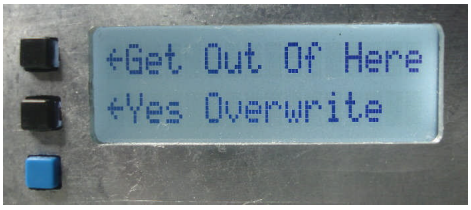
1. In the PICAXE Programming Editor select the 'File Menu' then 'Save As…"
2. In the 'Save' window rename the program to one you will remember as containing your calibration data then press Save

Note that all cal data is saved automatically during the calibration process but entries placed in this table are the only written record of this data. Not all calibration data is stored in EEPROM in a user friendly way. ATR & DTR for example are saved in the Clock Control Register as raw numbers that bear little resemblance to the capacitance or ppm.

Write the EEPROM

To complete the calibration all data required to operate CleverLoad is stored in the EEPROM. The five key calibration values are already stored in EEPROM. This was done as various parts of the calibration routine were completed. This task loads housekeeping data, a table that contains special characters that are loaded to the display when the application program initializes. They are used to render the bargraph and battery symbols. This action also saves the antilog table which is loaded from EEPROM by the application program to convert dBm to Watts. Data is also written that is used in conjunction with the application program to set the display backlight level. CleverLoad will not work properly without this data in EEPROM. To write the EEPROM

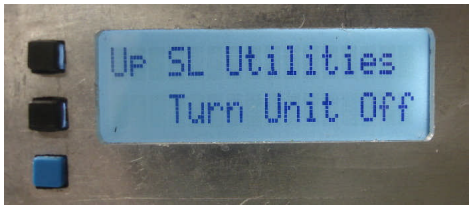
1. Navigate to the 'Write EEPROM menu and press Sw3. Two options are presented on the next screen.
2. Press Sw1 or Sw3 to exit the subroutine. Pressing Sw2 will overwrite the EEPROM



3. When the EEPROM write is complete the display changes to confirm the EEPROM has been written.

4. Press Sw3 to exit this section.

CleverLoad Calibration & Initialization is now complete.
Navigate to the last menu item to turn the unit off.



Press Sw3 to turn CleverLoad off.
Load the application program into the PICAXE Programming Editor and then download it to CleverLoad. The unit is now ready to accurately measure RF power.

Recover from EEPROM memory loss without recalibrating

The ISL2026 EEPROM memory is left locked after calibration so it's unlikely that the EEPROM memory will ever be corrupt. But mistakes happen so just in case here's a way to recover calibration data without having to recalibrate CleverLoad. This process assumes that you have written down or saved the calibration data for ATR, DTR, 0dBM, Sf and SfP parameters as instructed in the 'Review And Record Calibration Data' section.

1. Restore the Clk Cal Freq data

    a. Navigate to the Clk Cal Freq menu item
    b. Select the Analog Trim submenu item.
    c. Use the Up Dn buttons to select the recorded ATR value
    d. Press Sw3 to save the reading and exit the menu
    e. Navigate to the 'Digital Trim' menu item and press Sw3 to enter.
    f. Use the Chg button to select the recorded DTR value
    g. Press Sw3 to save the choice.
2. Restore the values for ZerodBm, Sf, and SfR.
    a. Load the calibration program into the PICAXE Program Editor. Scroll to the section named "RECORD CALIBRATION DATA FROM THE 'SHOW CAL DATA' SUBROUTINE IN THIS SECTION' This section can be found at about line 860.
    a. Uncomment the ZerodBm, Sf, and SfP lines
    b. Load this modified program into CleverLoad.
    c. Navigate to the 'Show Cal Data' subroutine and run it. This will enter the values for 0dBm, Sf, and SpF into RAM.
    d. Navigate to the 'Write EEPROM' subroutine and select it by pushing Sw3.
    e. Select <-Yes Overwrite to save the three cal data entries and write all other EEPROM data.

DO NOT SAVE OR CONTINUE TO USE THIS MODIFIED PROGRAM. Just close it without saving. Then download the CleverLoad application program to the unit.

How to configure CleverLoad for use if you can't calibrate it

1. Navigate to the Write EEPROM subroutine then push Sw3
2. Two options are presented, choose <-Yes Overwrite by pressing Sw2
3. The screen should indicate that the EEPROM has been written and will return the user to the main menu.
4. Navigate up to the Set Clock selection then press Sw3. This will display the current clock settings.
5. If the date or time is incorrect set the clock by following the instructions in the 'Set the ISL12026 Clock' section. Otherwise press Sw3 to be returned to the main menu.
6. Navigate to the 'Turn Unit Off' menu item and press Sw3 to turn the unit off.
7. Download the application program to CleverLoad.

How to Download a program to CleverLoad

This procedure requires a computer running the PICAXE Programming Editor, the program to be downloaded to the CleverLoad and a modified PICAXE serial cable connecting the computer to CleverLoad.

1. Start the PICAXE Programming Editor application.
2. Using the 'File' menu select 'Open' and navigate to the program to be loaded
3. Connect the serial cable from the computer to CleverLoad.
4. Make sure that the Programming editor's Serial Port is working. To do this
    a. In the Program Editor select 'View' menu then 'Options...'
    b. Select the 'Serial Port' tab
    c. Make sure the radio button identifying the port is correct otherwise select a port then push the 'Test Port' button and follow the instructions.
5. Download the selected program to the CleverLoad PICAXE Processor. As the 20X2 used in CleverLoad doesn't have a reset switch and the unit uses a soft power switch do the following:
    a. In the PICAXE Program Editor click on the 'PICAXE' menu item then click on 'Program…'
    b. The 'Downloading…' window appears followed by the 'Connecting to Hardware…' window
    c. When the 'Connecting to Hardware…' window appears push Sw3, the switch just below the display and hold it down until the download is complete.

When loaded a splash screen will identify the loaded program and then in the calibration program the main menu will appear