LV8961H Parameter Setup for EVB and GUI

Version 0.4

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Scope

- This document will provide first time users of the LV8961H an introduction on how to set up the evaluation board, graphical user interface and get their motor running.
- Two parametrization sections are provided:
  - Setting up general system parameters for startup and operation using trapezoidal mode.
  - Activating sinusoidal mode and find tuning of parameters for quiet performance.
- For detailed setup for production, once you feel confident with the information provided herein, please contact your onsemi applications representative.

What you need

- LV8961H Evaluation Board
- LV8961H Communication Board
- The motor to be parametrized
- Mini USB cable
- Power supply suitable to run the motor
- Digital multimeter with current measurement to measure supply current
- Oscilloscope with at least two channels
- Current probe
- A PC or Laptop with Windows 7 or higher to run the GUI

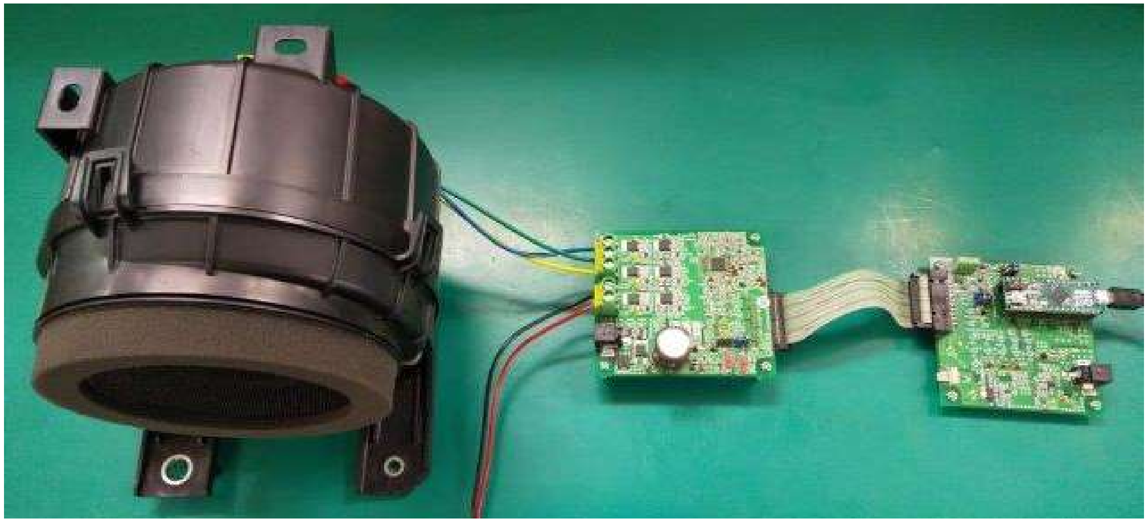
Table of Contents

Evaluation Board Setup

Do you have everything and is it set up correctly?

LV8961H Evaluation board set up

Here is how to connect the motor, LV8961H EVB and communication board:



- Left: Connect Motor phase U, V, W to EVB's U, V, W. The COM (black line, if any) may not be connected
- Center: Connect EVB to power supply with VS-GND (typ. 12V) and connect the EVB and the communication board with the supplied connector cable.
- Right: Connect Communication board to PC via USB (USB-micro)

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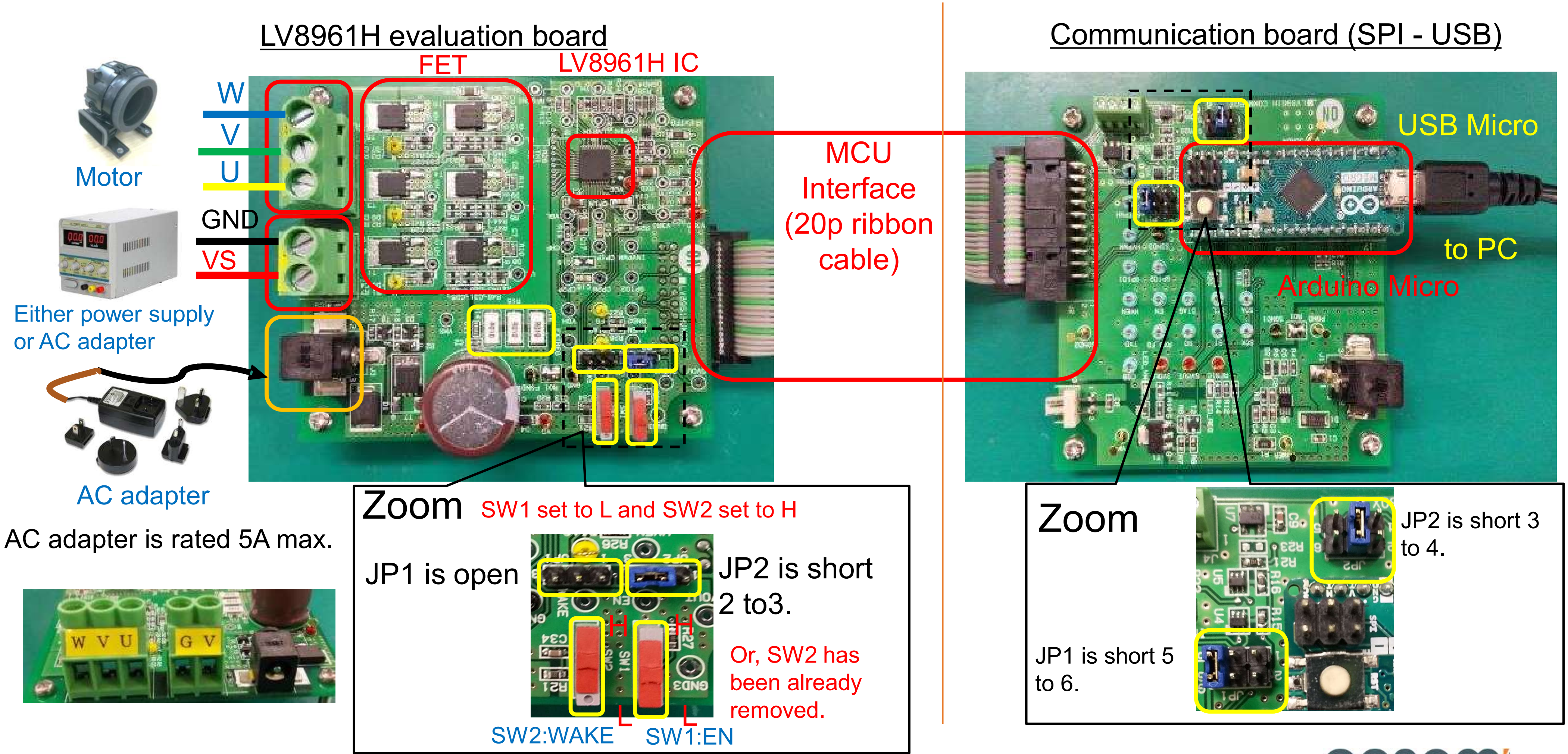
LV8961H evaluation board and communication board setting



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Setting Motor parameter: Current Limit

The shunt resistor and the current limit threshold set the maximum <u>operating</u> current for the application*. It is important to use a realistic value for the operating current (shunt) as this influences motor startup.

The current limit is determined by V_{CL} the voltage across the current sense resistors on the EVB: R14, R15, R16 and the internal register: CLSEL.

The current limit is given by the following equation.

$$I_{\lim\_1} = V_{CL} \times \frac{1}{R_{cs}}$$

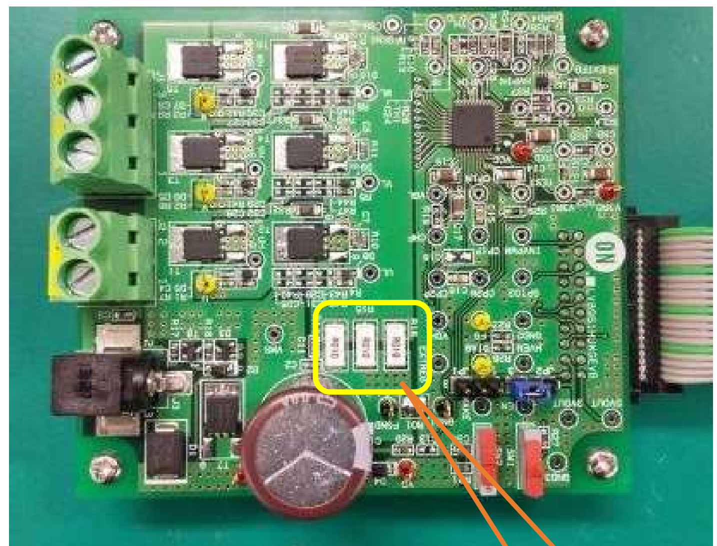
$$R_{cs} = \frac{1}{\frac{1}{R14}+\frac{1}{R15}+\frac{1}{R16}}$$

CLSEL=1⇒ $V_{CL} = 100mV$
CLSEL=0⇒ $V_{CL} = 50mV$

Default current limit is 30A in this board:

Because 3 resistors of 10mΩ in parallel =0.33mΩ.

Initial limit threshold voltage V_{CL} is 100mV.



* There is also an overcurrent shutoff which is defined by register OCSEL and will shut down the motor at V_{OC} = V_{CL}+ 25,50,75 or 100mV as measured across the shunt.

GUI Installation

How to install the Graphical User Interface

Arduino Driver Installation

1. Connect the Comm Box to the PC using the USB micro cable.
2. The Windows OS will try to install driver on its own. Wait for 5-10 minutes.

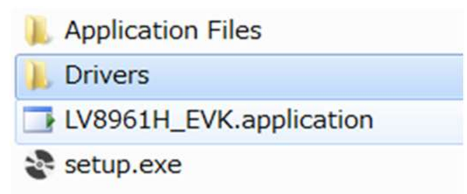
If installation fails:

3. Click on the Start Menu and open the Control Panel.
4. Open the Device Manager.
5. Either under ‘Ports (COM & LPT)’ or ‘Other Devices’, you should see an open port named ‘Arduino Micro’.

6. Right click on the ‘Arduino Micro’ port and choose the ‘Update Driver Software’ option.

   If the update driver software option is not available, then the Windows OS is still trying to install the driver on its own. Please wait till the OS finishes self-try.

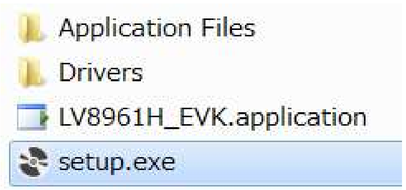
7. Next, choose the "Browse my computer for Driver software" option.
8. Finally, navigate to and select the driver file named ‘arduino.inf’, located in the ‘Drivers’ folder.



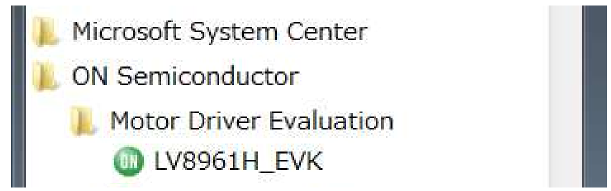
9. Windows will finish up the driver installation from there.
10. When the installation is successful, the recognized Arduino Micro port with the port number is shown in the Device Manage.

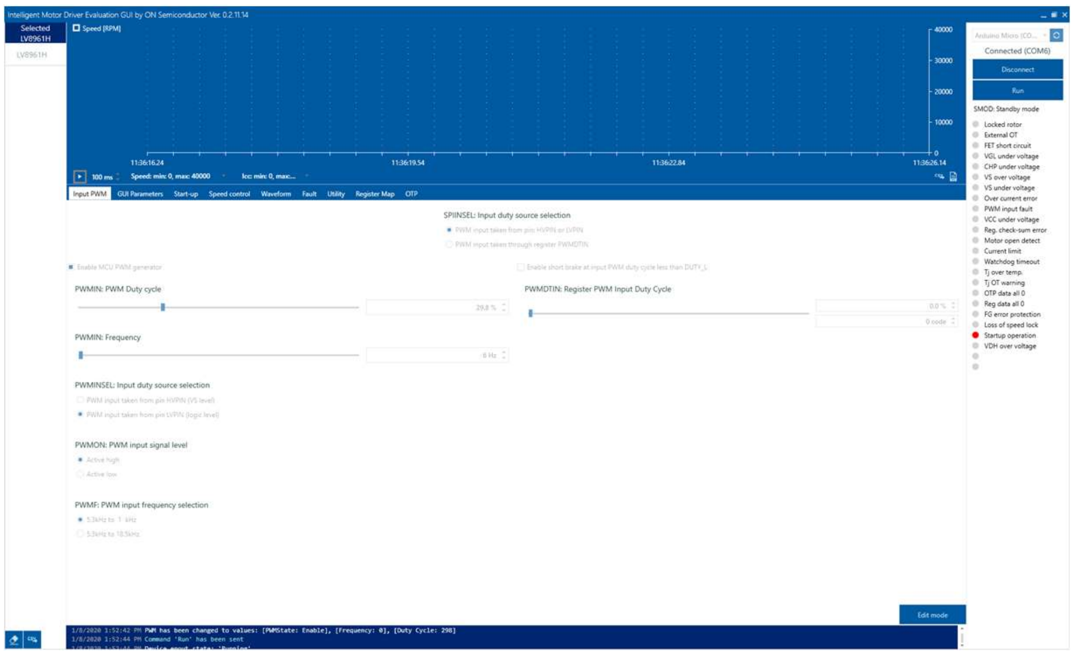
GUI Installation

11. Run setup.exe of the installation package



12. Launch the program from the side-bar program launcher





Running your Motor

Using „Default“ Parameters to get the motor running!

A little adjustment may be required...

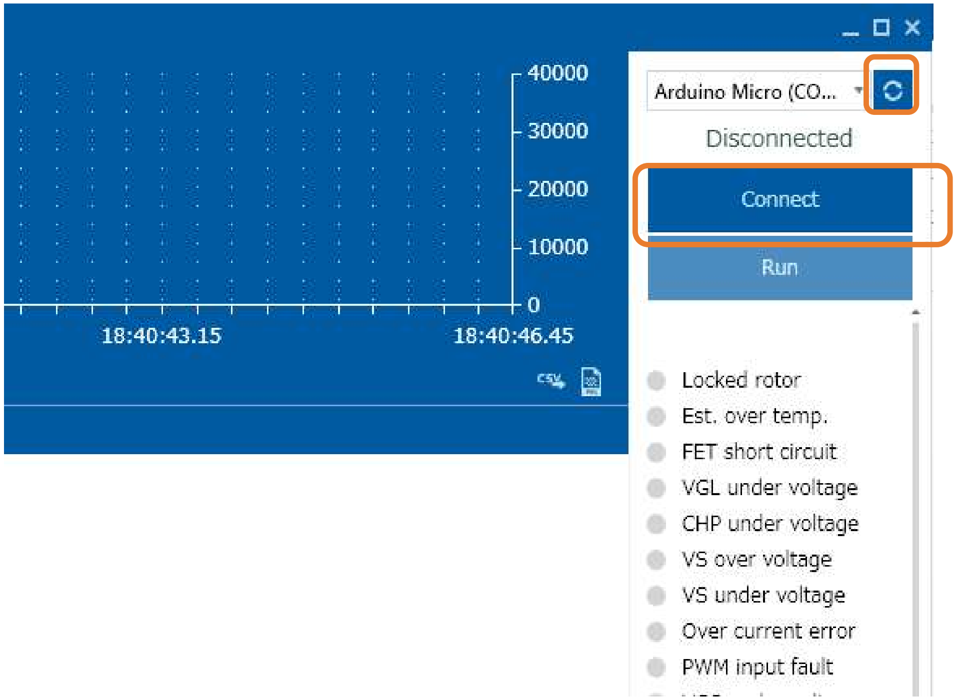
Power-up Sequence

- Connect the evaluation board and the communication board with the ribbon cable
- Connect a motor to the evaluation board
- Connect a power supply to the evaluation board
- Power-on the supply to a voltage between 12V and 24V
- Connect the USB cable to the communication board and a PC
(USB connection i.e. microprocessor power-on must be last)
- Start the GUI program: „ON Semiconductor\LV8961H_EVK“

Caution:
The following section requires the motor to run up to maximum speed.
You MUST ensure the motor is <u>secured safely</u> to prevent harm to yourself and your equipment!

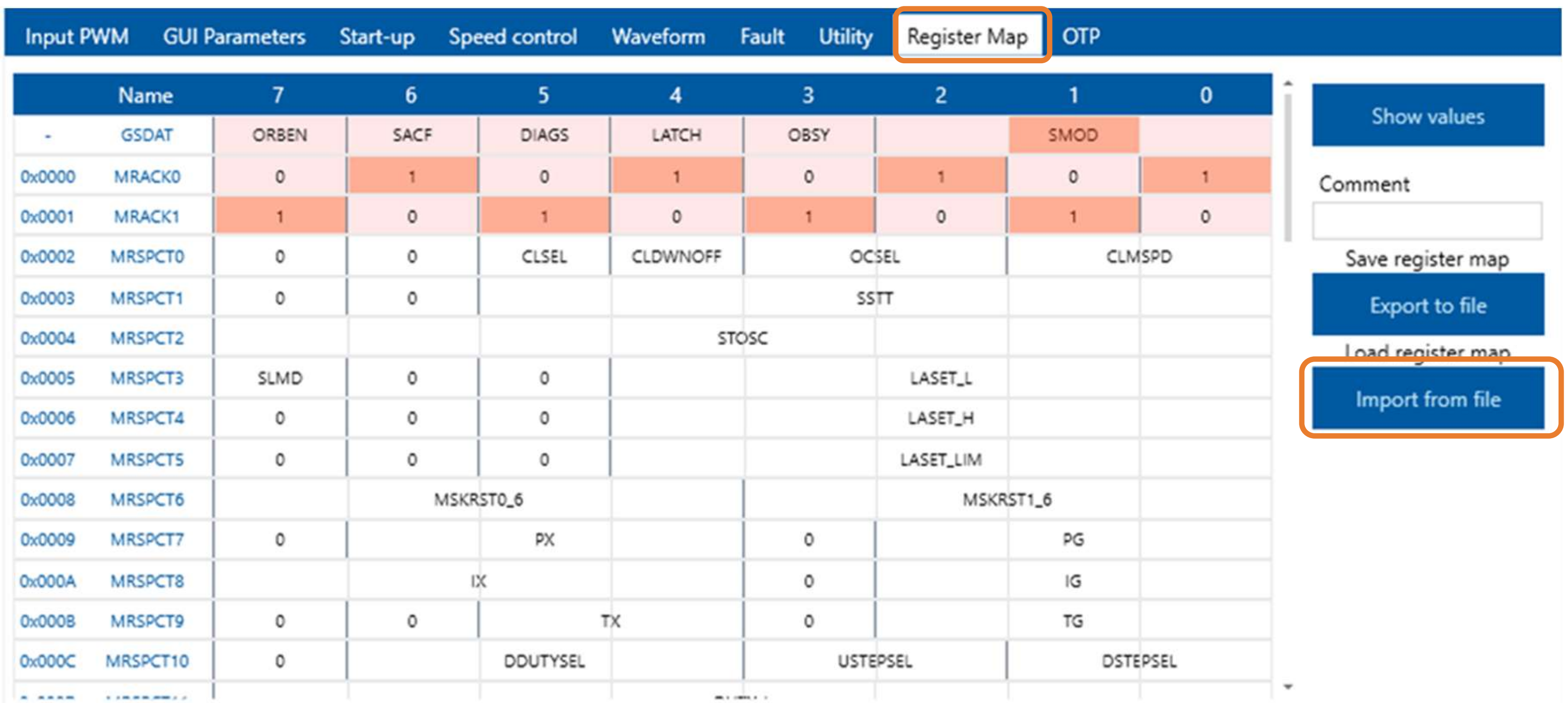
GUI for LV8961H EVB: USB Link

1. Click the button to identify potential COM ports
2. click the "Connect" button on the upper right.



GUI for LV8961H EVB: Parameter File Import

It is possible to load and save parameter setup files. For easier startup onsemi has provided an initial „LV8961H_Default.csv“ setup file which should run most motors out of the box.
Once you have adjusted parameters and are successfully controlling your motor, save the file under a specific file-name.



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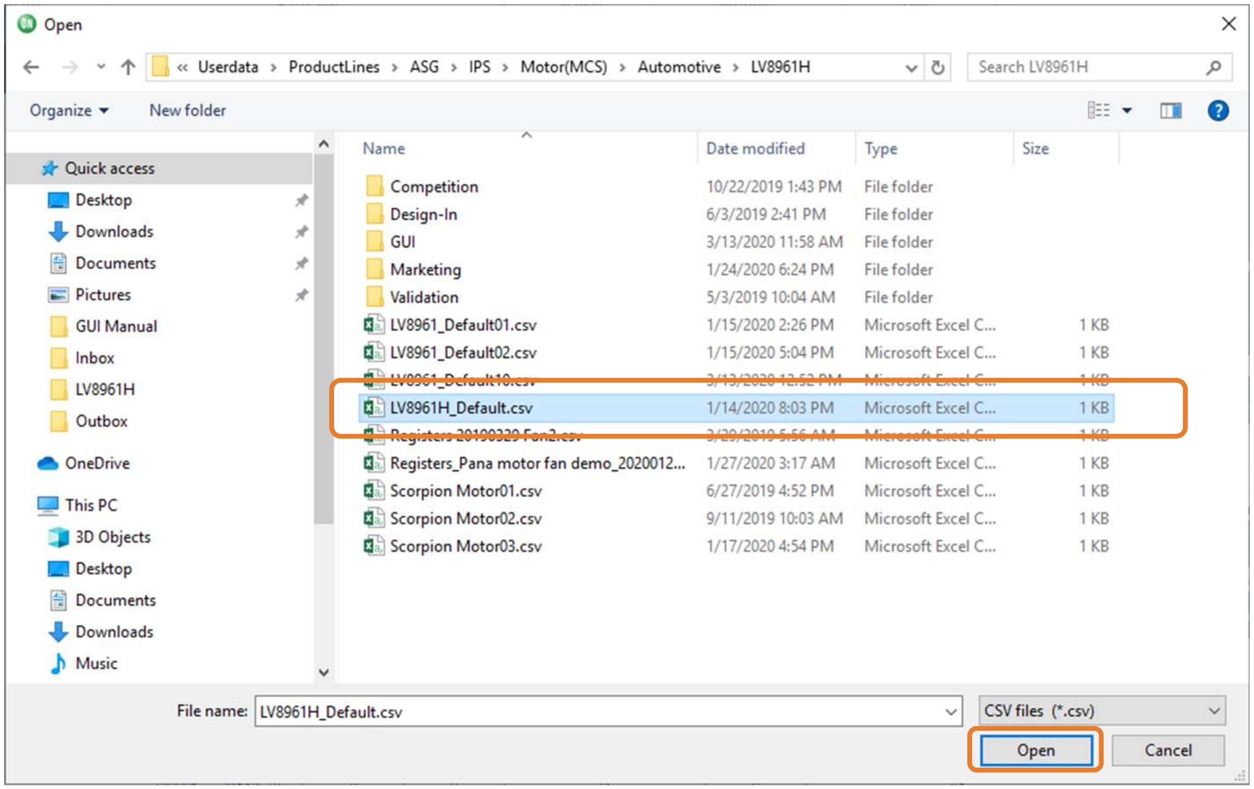
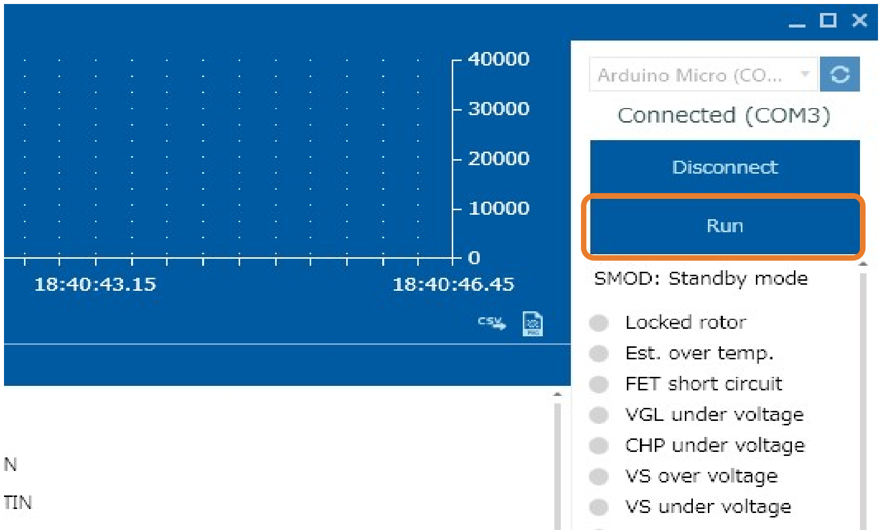
GUI for LV8961H EVB: Import File Selection

1. Select “Import from file”
2. Select the default startup parameter set “LV8961H_Default.csv”
3. Click **<u>O</u>pen** button



Running a Motor

Click the „Run“ button and start rotating the motor



The motor will start at a 25% duty cycle operation.

You will see two errors:

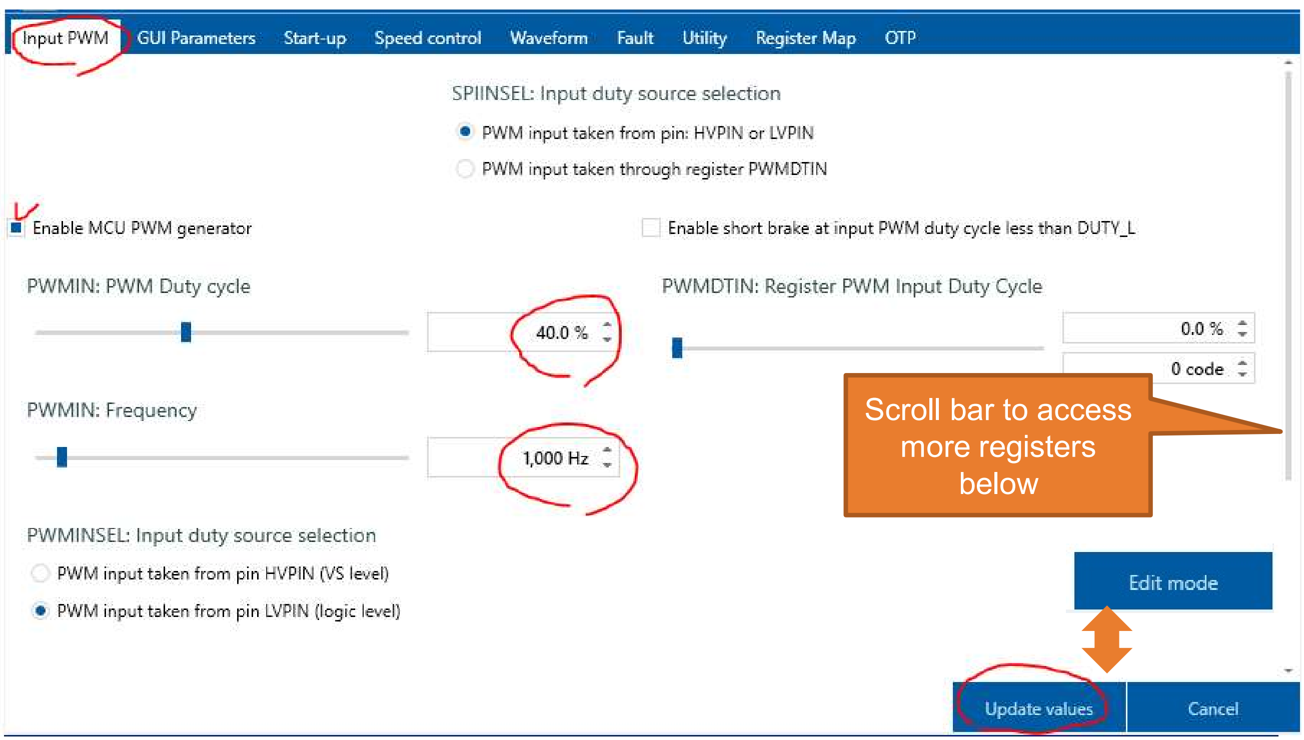
- **Watchdog timeout**
  is because no watchdog is triggered and is ignored.
- **PWM input fault**
  is because no PWM input signal is detected. The result is defined by register ZPSEL and results in the 25% duty cycle safety operaton.

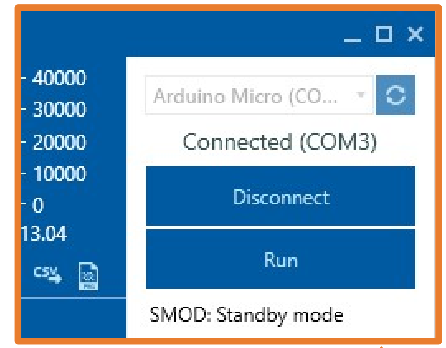
Next we will enter a PWM input signal to control the motor speed.

Note: Should you experience startup issues, consult section:
„Adjustment SSTT(soft start time) & STOSC(startup commutation frequency)“

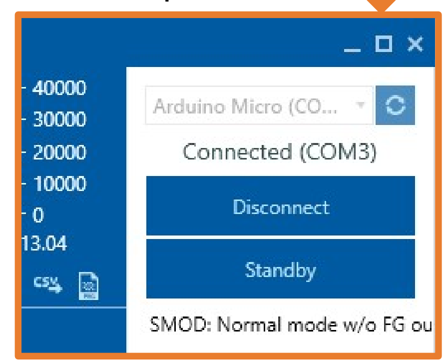
Using the GUI to change the speed

1. Click “Input PWM” tab
2. Click “Edit mode” button
3. Click „Enable MCU PWM generator“
4. Set PWM duty cycle with the slider bar or the text box, 40% for the very first time trial for safety
5. Click “Update values” button
6. Click “Run” to run
7. The “Run” button changes to “Standby”





8. Click “Standby” to stop



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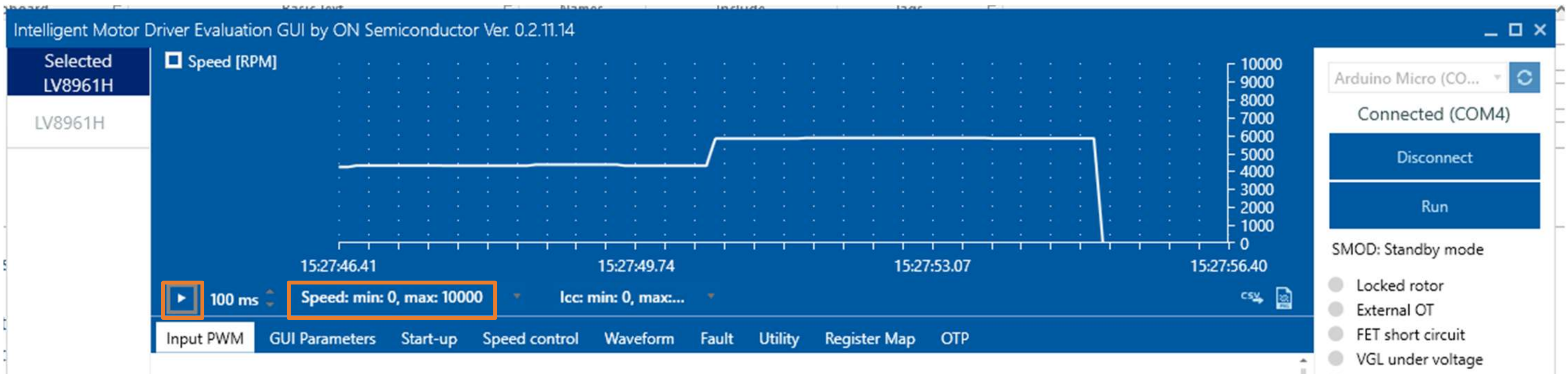
Confirmation of Rotation of Motor

The blue window allows speed tracking.

The rotation speed is displayed on the graph when ▷ is pressed.

Press Speed: min ... to change the scale of the Y axis.



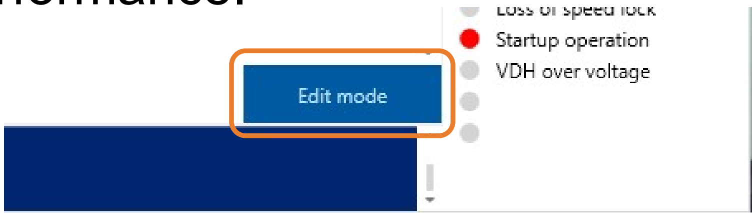
Motor Parameter Tuning

How to improve performance using trapezoidal mode.

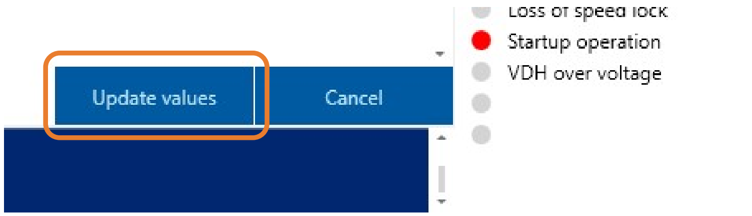
Overall sequence of register setting tuning

- Set motor parameters: number of poles and the current sense resistance.
- Setup the input to motor duty cycle conversion ratio.
- Set the open-loop startup parameters:
- Tune the lead angle parameter for optimal performance.

To edit parameters, the GUI must be unlocked by clicking on „Edit mode“ at the bottom right. You may have to scroll to see this.



After editing, click „Update values“ to save the parameters to the IC.

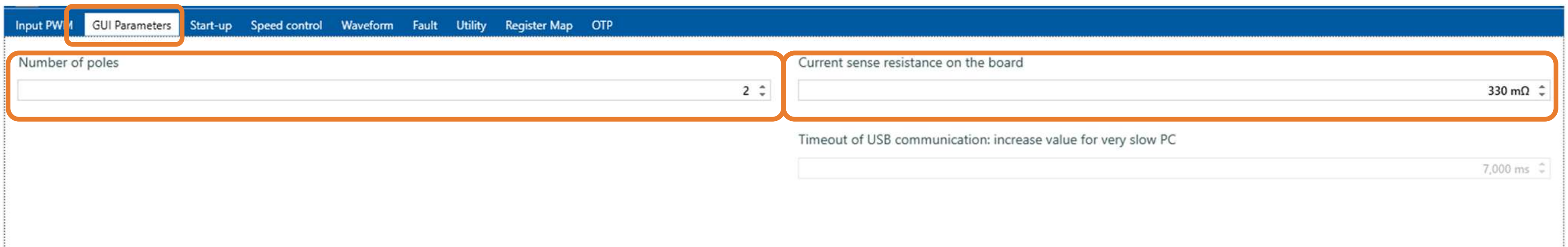


Note:

Some parameters can be adjusted in “Run” mode, others only in “Standby” mode. Parameters that cannot be adjusted in the current operation mode will be greyed out!

Setting Motor parameters

GUI Parameters are primarily for displaying the waveform at the top of the screen. Adapting the number of poles to the motor used will display the physical speed of the motor rather than the electrical revolutions (Number of poles = 2)



1. Select „GUI Parameters“ tab
2. Set number of poles for motor in “Number of poles”. (e.g. set 10 for a motor with 10 poles).
3. Set current sense resistance (R_{cs}) on the board. (e.g. set 3mOhm for 3mohm resistance).
4. Click “Update values” button at the screen below.

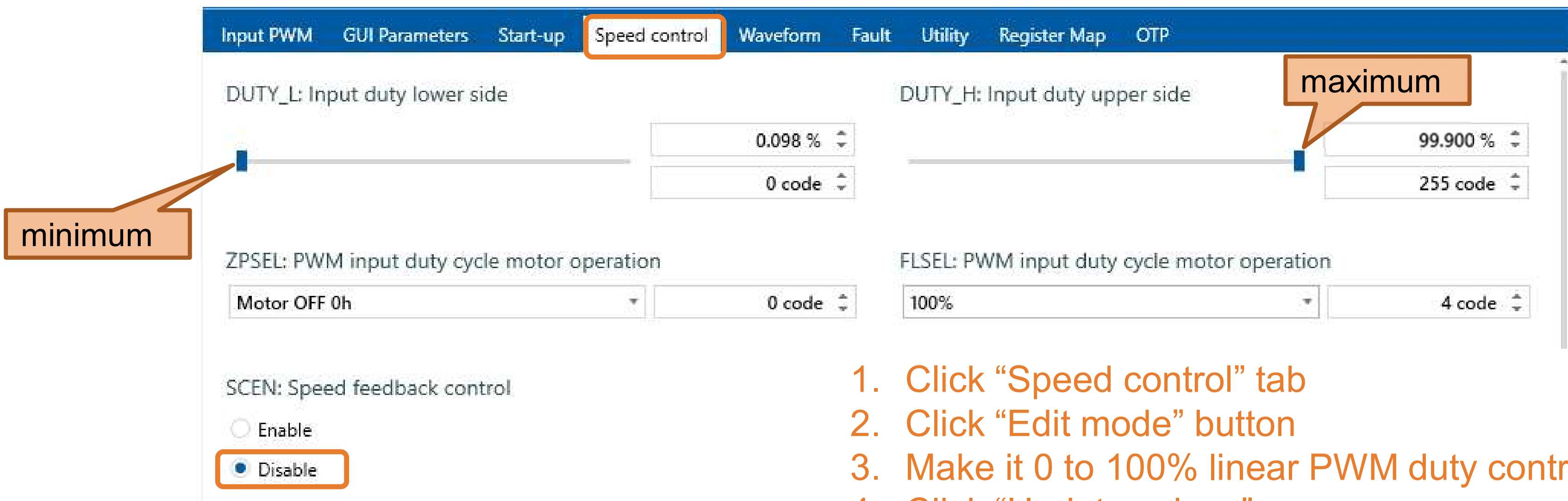
Note:

These parameters can be saved but they will be stored in a separate file from the LV8961H register map file.

Input duty cycle to motor duty cycle translation

Define how the input duty cycle is translated to motor duty cycle and set the behaviour outside that range.

- Input duty cycle below DUTY_L behaviour is defined by ZPSEL
- Input duty cycle between DUTY_L and DUTY_H corresponds to motor voltage 0%VS to 100%VS.
- Input duty cycle above DUTY_H behaviour is defined by FLSEL



1. Click “Speed control” tab
2. Click “Edit mode” button
3. Make it 0 to 100% linear PWM duty control
4. Click “Update values”

Note:
The LV8961H cannot drive motors faster than about **40000RPM** electrical! Above this speed, drive becomes erratic indicated by a change in noise and dropped FG pulses. Avoid operating above max speed by reducing input duty cycle.

Startup Behavior

- LV8961H uses open-loop startup until a valid Back ElectroMotive Force (BEMF) signal allows for closed-loop control.
- The parameters SSTT and STOSC define open-loop startup. STOSC is the startup speed defined in 1/frequency, while SSTT defines the startup time.

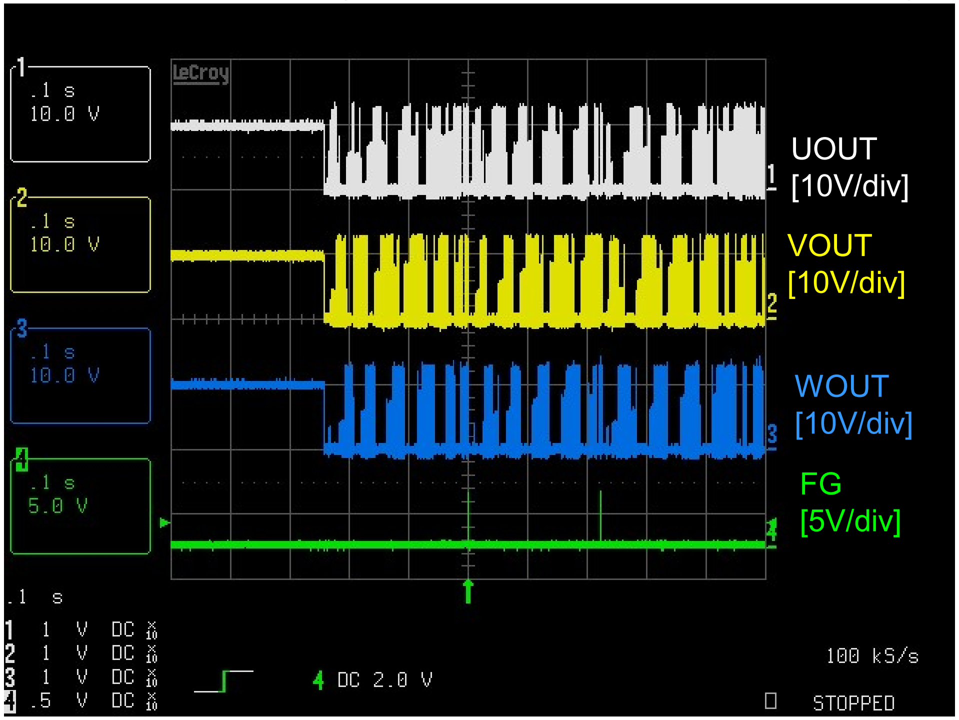
1. Test startup behavior by clicking on „Standby“ and „Run“ button.
2. Default parameters are set for 3.4s ramp up time. For faster startup reduce this time.

Startup issues can be caused by a startup that is too fast, or by a wrong startup speed. See the next two slides for examples on how to solve startup issues.

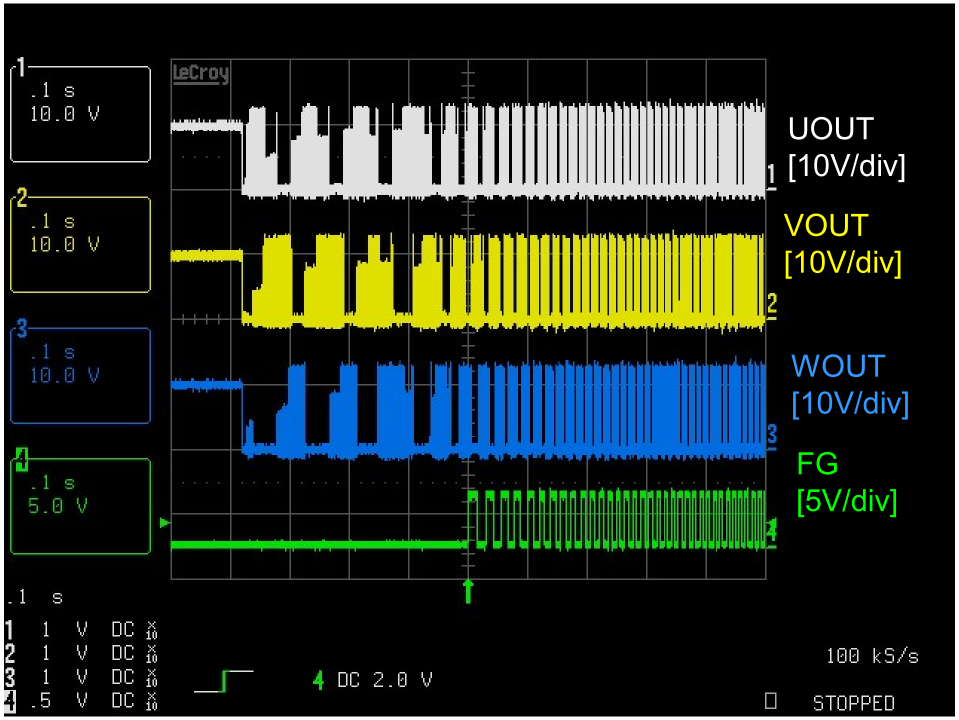
Startup Speed (STOSC)

The startup speed is defined as the startup period STOSC in s (1/Hz).

- When “STOSC” is too small, large heavy motors may not start, the waveform at startup looks like the left figure, and the motor does not rotate normally. In this case, increase “STOSC” until motor rotates normally.
- If STOSC is too large excessive current flows during startup.



Startup fails because STOSC is too small.

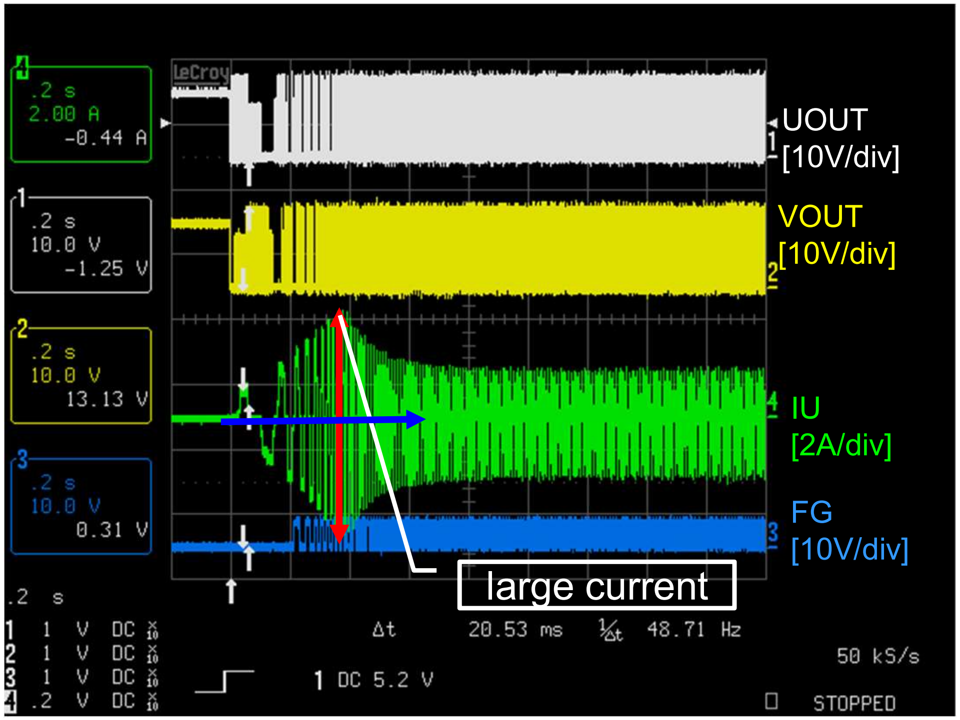


Startup works by increasing STOSC

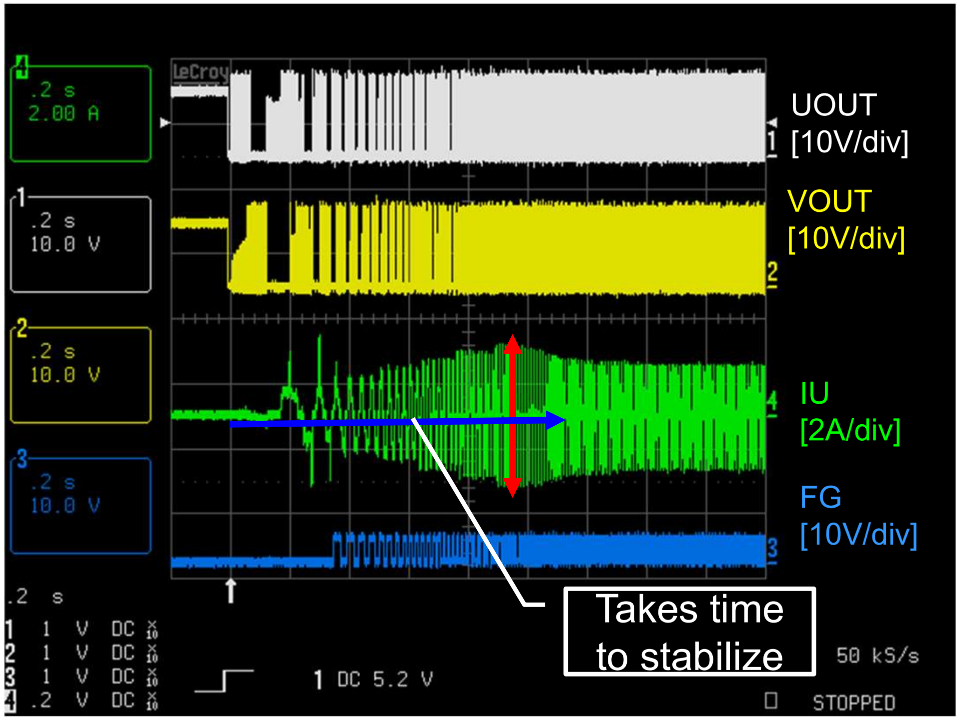
Soft start time (SSTT)

During soft start time the motor current is increased from 0 to current limit (measured at the current shunt).

- When "SSTT" is small (left waveform), stable operation starts in a short time, but inrush current gets larger.
- If "SSTT" is increased (right waveform), the time to stabilize is longer, but the inrush current is smaller.



SSTT=small ->Immediately stable, but the current is large



SSTT=large ->It takes time to stabilize but the current is small

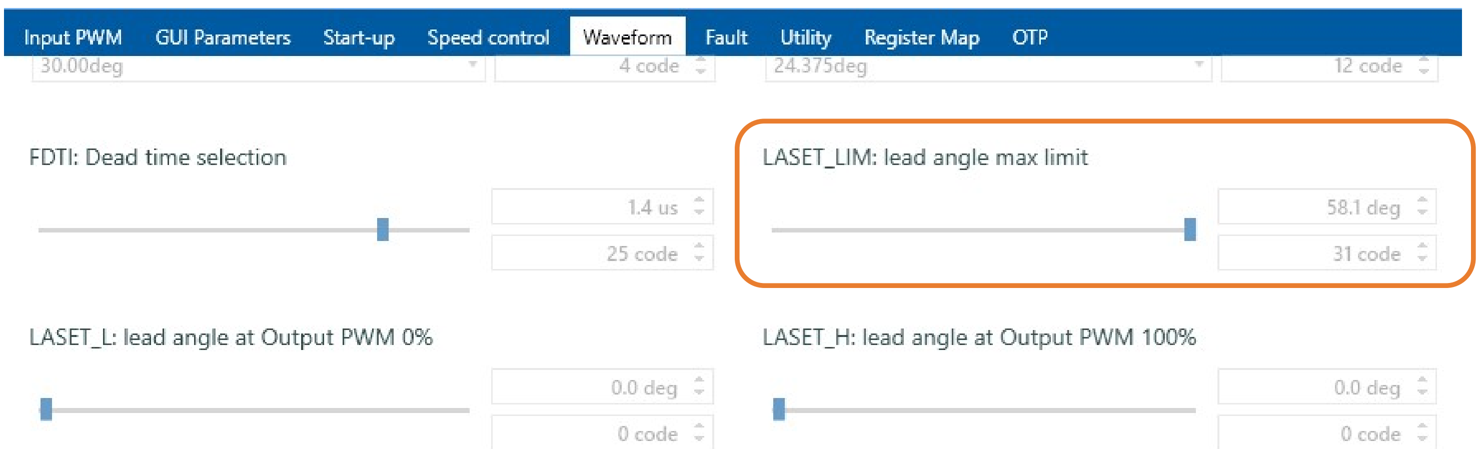
Lead Angle Adjustment

Two factors require lead angle adjustments:

1. The motor architecture may have effects on the flux distribution within the motor.
2. The LV8961H control loop introduces an inherent delay from motor parameter measurement to application of the motor voltage. This delay becomes more important at high motor speed.

To compensate for this the LV8961H allows programming of a low-speed 0%VS lead angle parameter LASET_L and a high speed 100%VS lead angle parameter LASET_H. The internal algorithm interpolates between the two.

Set LASET_LIM to max, to have full flexibility in lead angle range!



Setting up the Lead Angle Limits

- A rough estimate for maximum lead angle can be done by monitoring the motor speed and supply current. (Track speed in the GUI scope window or measuring the FG frequency).
- Use no-load operation for this (with fans, block the airflow) and ensure the motor is secured! In no-load, the motor current should be largely constant.

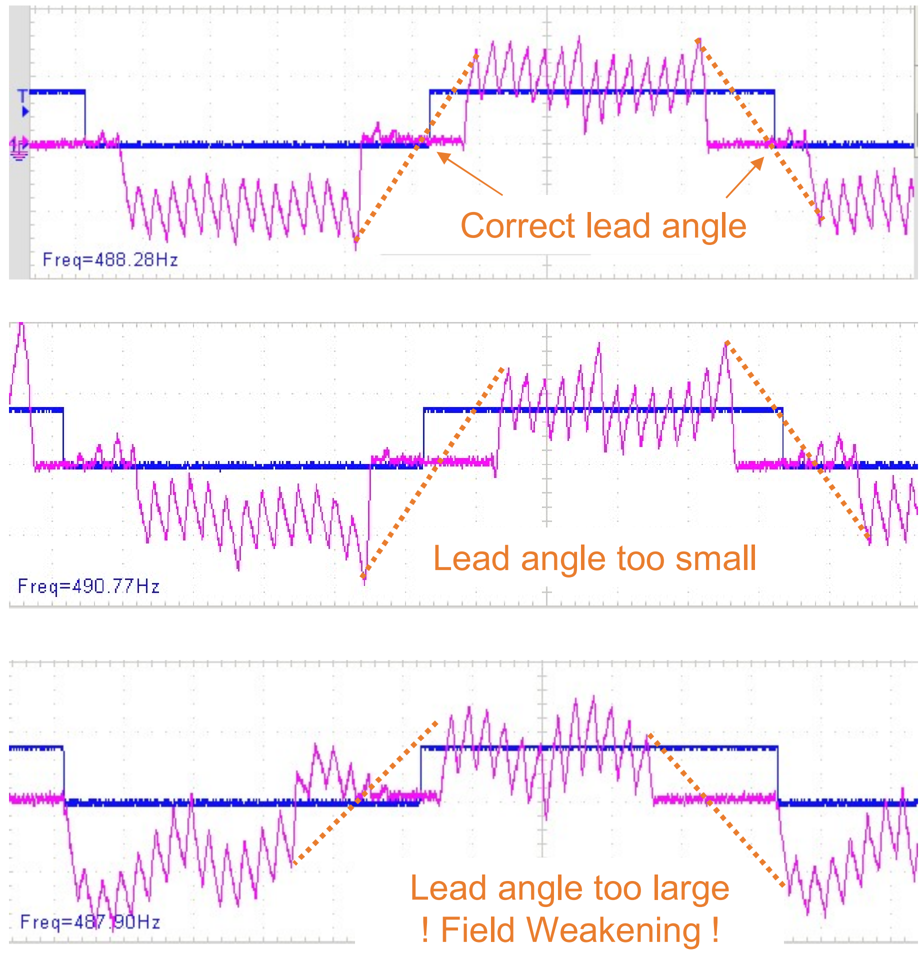
1. For a first approximation leave LASET_L at 0.0deg and focus on LASET_H.
2. With the motor at 100% duty cycle*, increase LASET_H until motor speed doesn't increase any more.
3. Then reduce LASET_H to the point where the current does not reduce significantly any more.

Note:
This method is very unreliable as it may result in driving the motor into field weakening, where the electrical field begins to supress the magnetic field, resulting in a smaller BEMF voltage. This is indicated by a noticeable increase in current. To prevent field weakening, use the visual method as described in the next slide.

* If 100% duty cycle exceeds 40000RPM use the duty cycle which generates maximum stable speed.

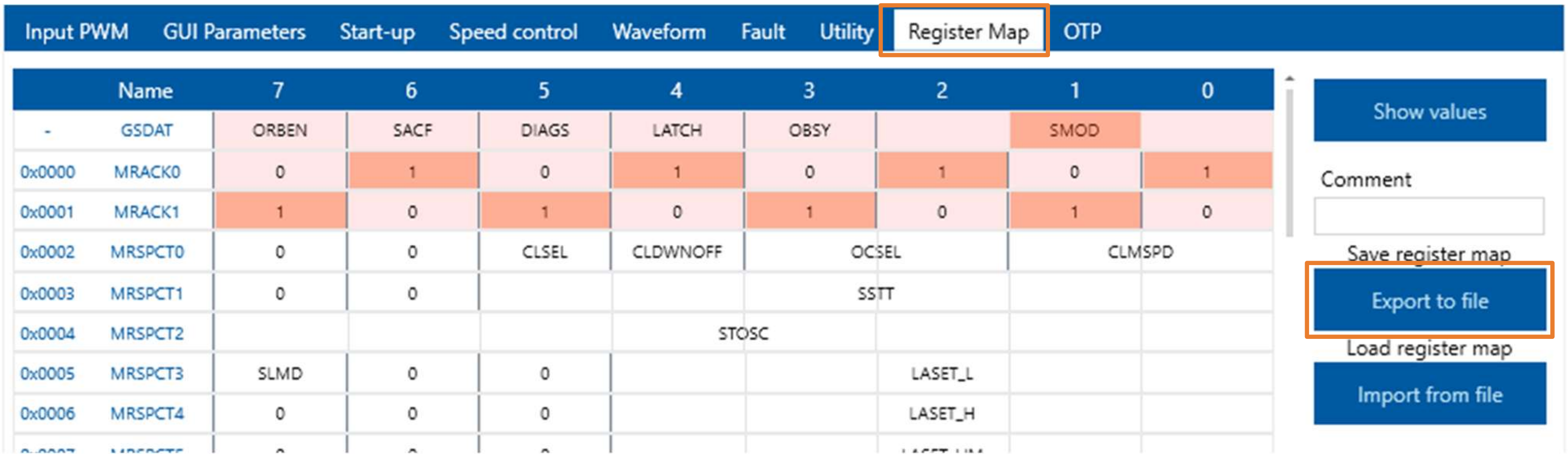
Visual Verification of Lead Angle setting.

- Monitoring the FG signal (blue) and motor phase U current (purple) it is possible to get a more accurate estimate of the correct lead angle.
- Run the motor at no load at 100% duty cycle and adjust LASET_H until the FG rising edge occurs shortly after the current zero crossing.
- To estimate the current zero crossing use an imaginary (orange dashed) line from the last negativ current peak to the first positive current peak.



Export to file

Save your tuning setting frequently under a file name of your choice!



1. Select "Register Map" tab
2. Click the"Export to file"
3. Give it a new file name
4. Save the file

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Sinusoidal Operation Tuning

How to run the motor in sinusoidal mode:

- Window mode selection
- Window width modification
- Phase angle adjustment

LV8961H Principles of Sinusoidal Operation

LV8961H is a three-phase sensorless predriver with sinusoidal two-phase drive (space vector modulation with flat bottom). This always activates all three driver outputs. To detect rotor position, the LV8961H monitors the BEMF zero cross timing in a small window. In the "window", the output is floating to sense the BEMF.

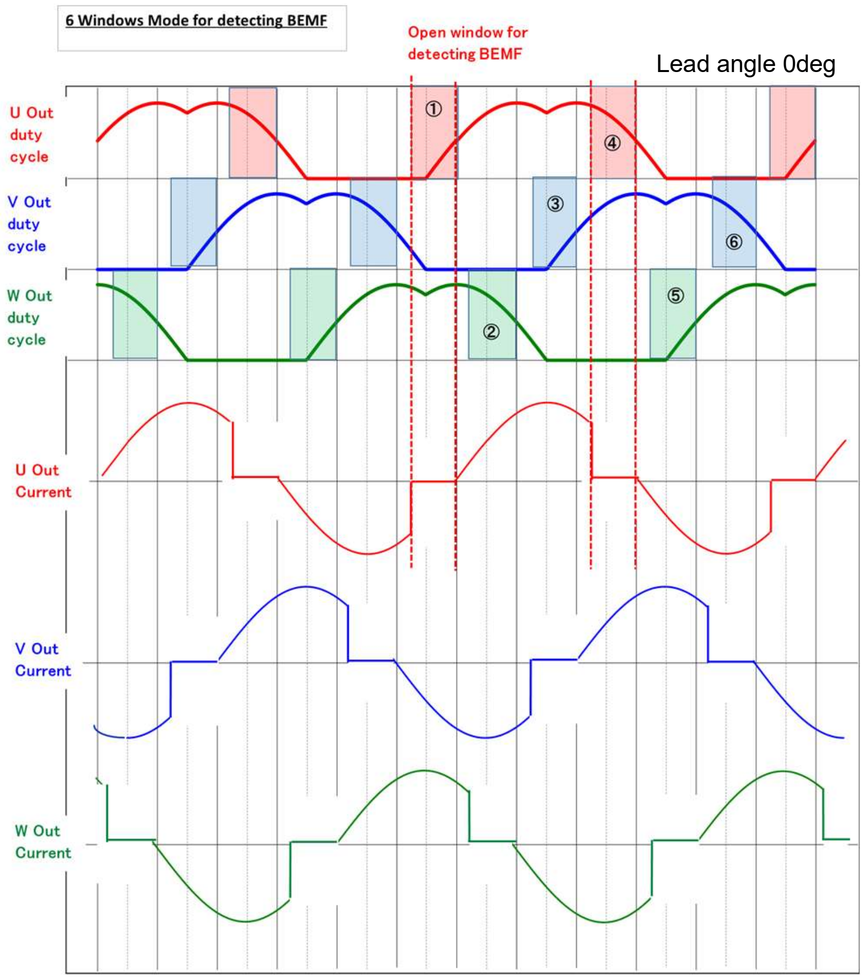
There are four selectable window modes for the detection window per electrical cycle.

- 6: all zero cross for all three phases (similar to trapezoidal commutation)
- 3: one rising zero cross for each phase
- 2: rising and falling zero crosses of the phase U
- 1: one rising zero cross of the phase U

Note:

If the LV8961H fails to detect a BEMF transition during it's window, it will revert to 6 window mode to re-synchronize.

LV8961H Window Mode Timing Chart



6-window mode

All zero cross (rising and falling) for all three phases will be detected by opening 6 windows per electrical cycle. The shaded sections (1-6) in the chart show the windows.

It gives best robustness to secure the all zero cross detection. However, the current waveform distortion will be higher.

3-window mode

One rising zero cross for each phase will be detected by opening 3 windows per electrical cycle. The shaded sections 1, 3, 5 in the chart show the windows used for 3 window mode.

Balanced (or same) waveform is applied among three phases.

1-window mode

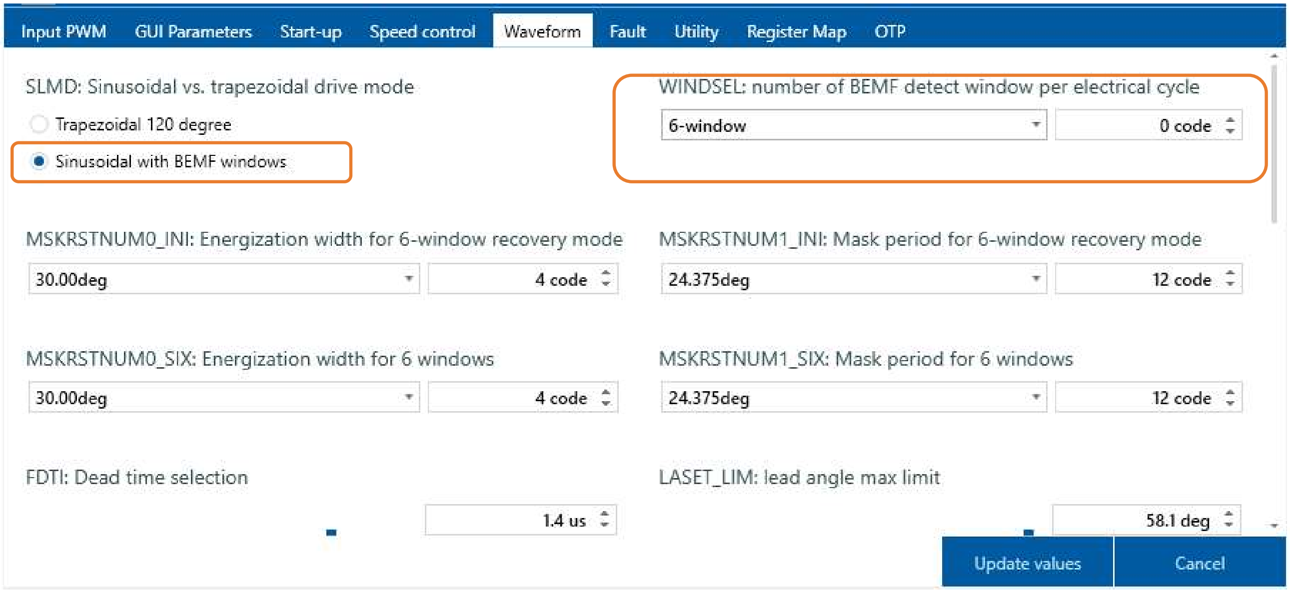
Rising zero crosses of only phase U will be detected by opening one window per electrical cycle. The shaded section 1 in the chart shows the window used. Only phase U has the window, and the others (V and W) don't.

The current waveform distortion will be minimized for the other phases.

Activating Sinusoidal Mode

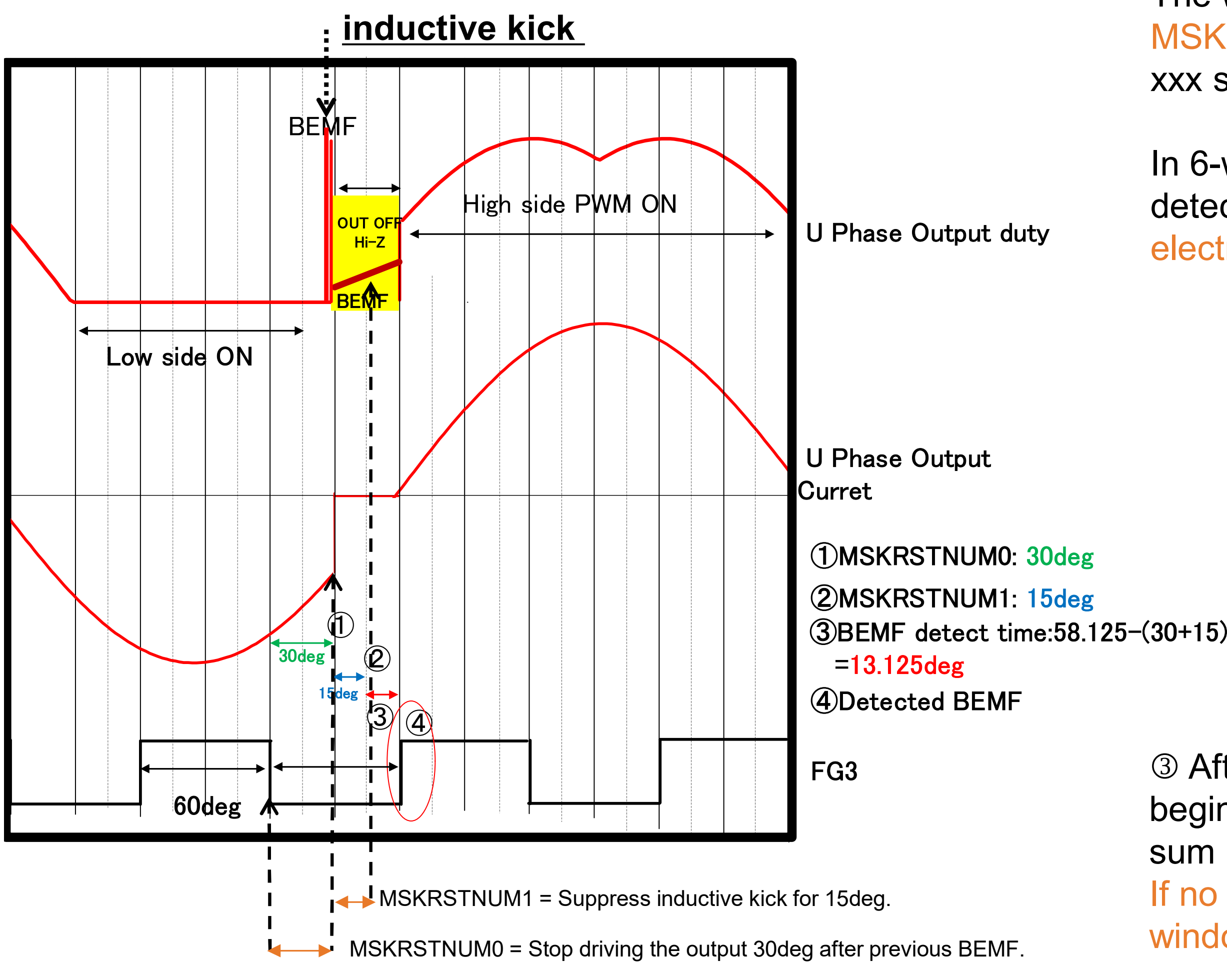
The parameters set in trapezoidal operation can be used to start tuning sinusoidal mode. Begin with 6 window sinusoidal mode and then try to reduce the window number.

- **6-window**
  Most robust for small motors with low inertia and possible load changes.
- **1-window**
  Quieter, better for high inertia motors with constant load.
- **3-window**
  Compromise between 6- and 1-window.



After choosing a window mode, it is possible to reduce window size to reduce noise even more!

BEMF Detection Window Size



The window width is defined by the register setting MSKRSTNUM0_xxx and MSKRSTNUM1_xxx. Where xxx selects which mode (1,2,3 or 6-window)is applied.

In 6-window mode, the interval between one BEMF detection and the next BEMF detection is 60deg electrical angle.

① MSKRSTNUM0 defines the time from the previous BEMF detection to the start of the window where the phase output turns off.

② MSKRSTNUM1 is a blanking period from the start of the window defined by MSKTRTNUM0 until BEMF sensing. This blanking time prevents faulty zero cross detection due to the **inductive kick** caused by the current flow.

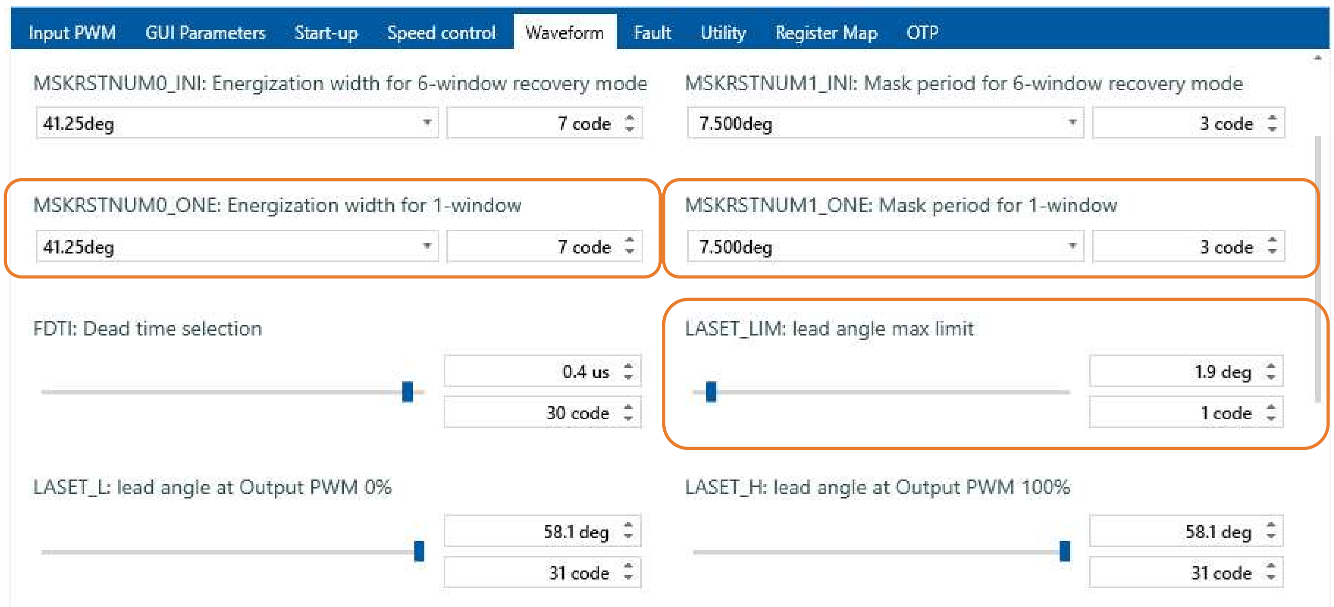
③ After time MSKRSTNUM0 + MSKRSTNUM1 the IC begins looking for the next BEMF transition④. This sum must be less than 60deg by definition.
If no transition is detected, the circuit will enter 6 window recovery mode!

Optimizing BEMF Window and Lead Angle

Reaching an optimal setting for sinusoidal drive is an iterative process. Use typical load and supply voltage:

1. Correct the lead angle to prevent current jumps and reduce the inductive kick.
2. Increase MSKRSTNUM0 to make the sensing window smaller. Reduce MSKRSTNUM1 to make the blanking period smaller.
3. Observe stability (e.g. if abnormal rotations trigger recovery mode, cfr. datasheet)

If stable repeat.



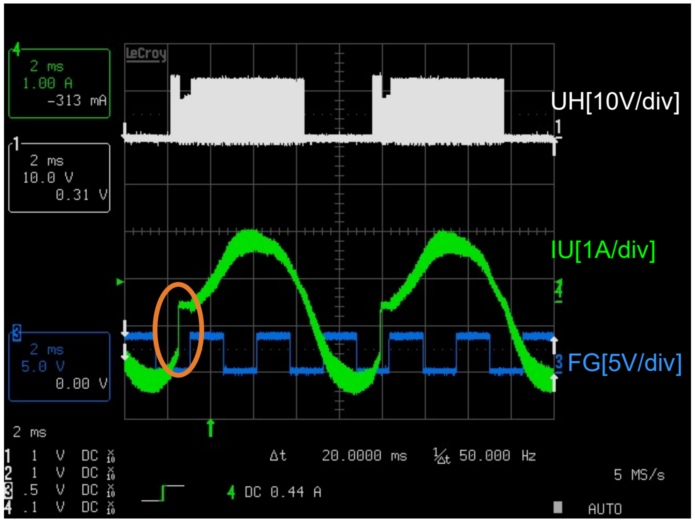
Optimal Lead angle and BEMF window width

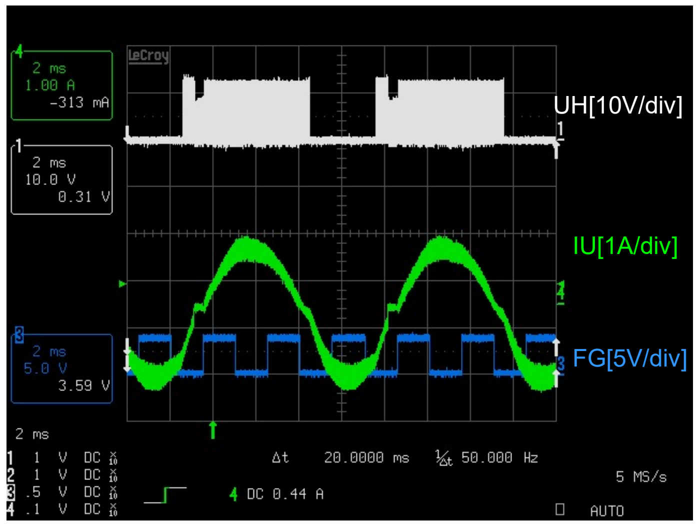
1. To get discrete lead angle points, set LASET_L and LASET_H maximum, and LASET_LIM to minimum.
2. Create a table for duty cycles from min to max in 10% increments.

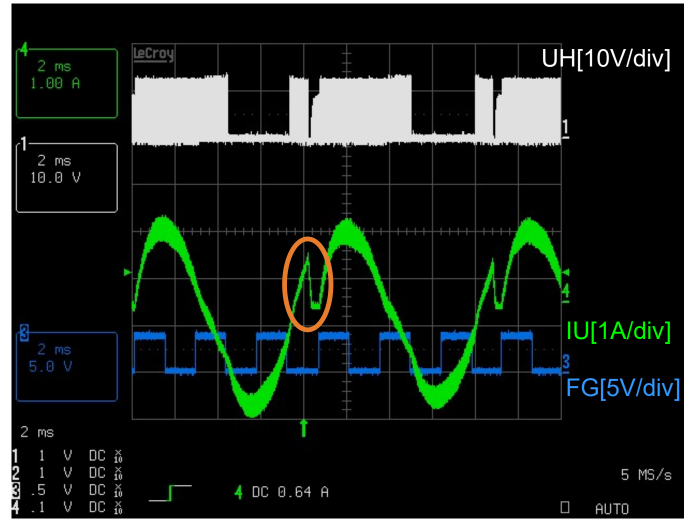
Duty Cycle	LASET_LIM	MSK0	MSK1	RPM
30%				
40%				
50%				
60%				
70%				
80%				
90%				
100%				

Step 1) Lead angle tuning

Confirm U phase and IU current. If the wave form is distorted e.g. similar to the left- or the right figure, change “mask width” and “lead angle” to decrease distortion similar to the center figure.





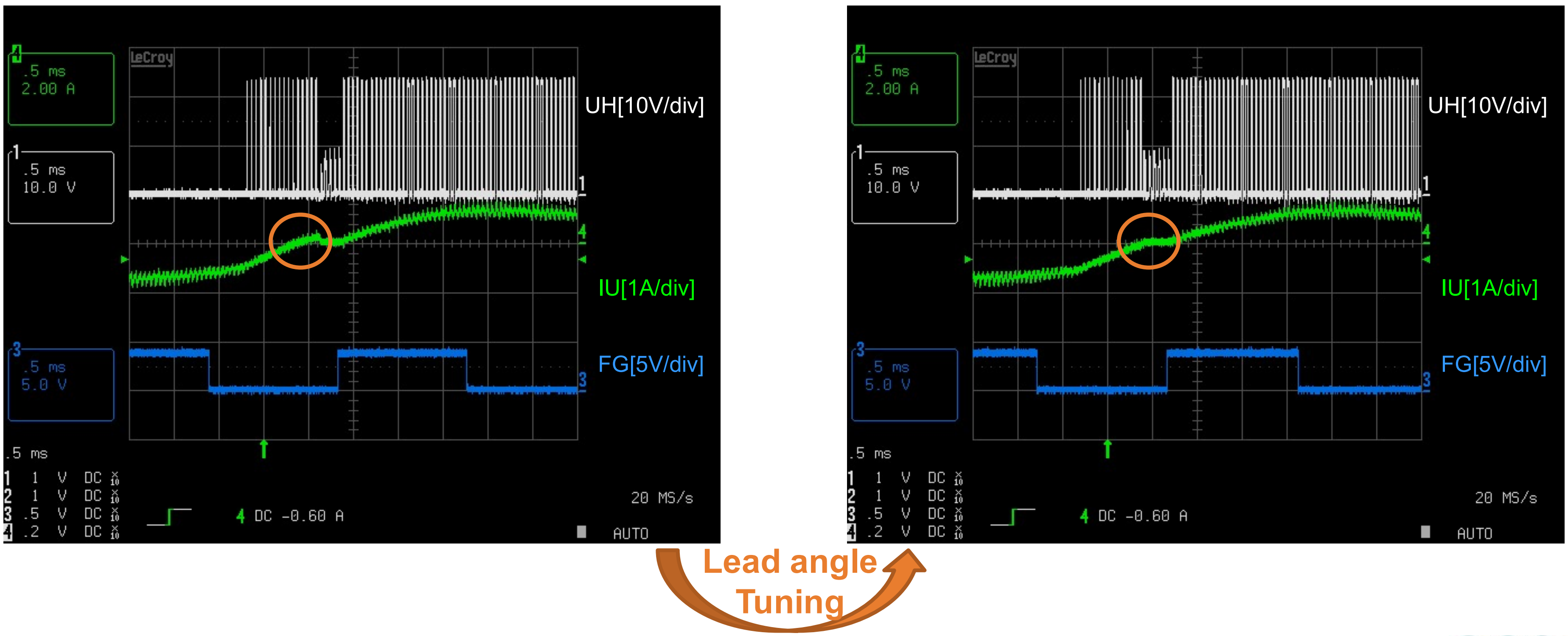


Increase lead angle

Decrease Lead angle

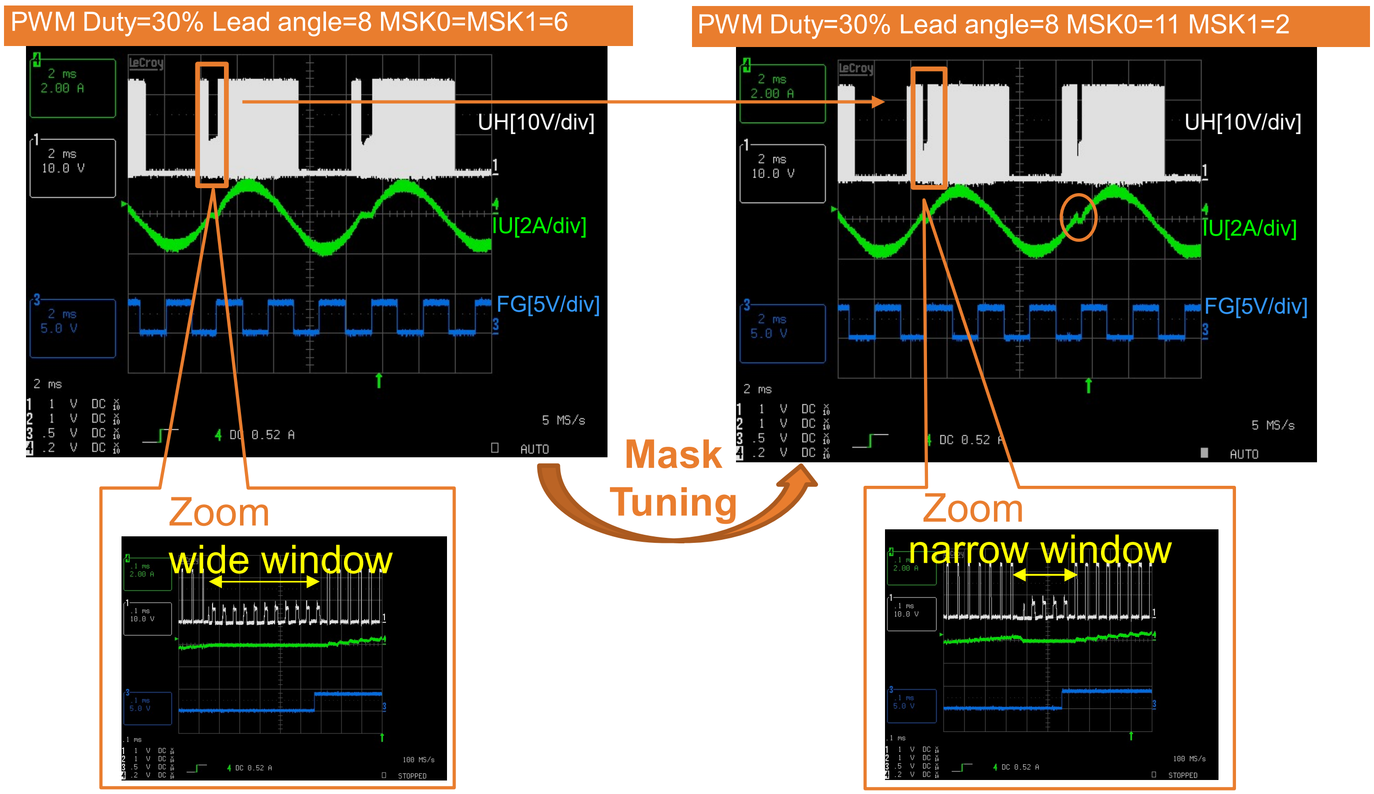
Lead Angle fine tuning

After adjusting the Lead angle and correcting the rough distortion, adjust the Lead angle by expanding the area near the zero crossing.
Operation is more stable if the zero current point is taking place within the window rather then before the window (right trace below).



Step 2) Mask Tuning

- At PWM Duty 30%, once the setting of the Lead angle that can suppress distortion of the current waveform is decided, adjust the Mask width (MSKRSTNUM0_ONE = MSK0, MSKRSTNUM1_ONE = MSK1) to make the BEMF observation window narrower.



If MSK0 is increased and MSK1 is decreased, it is visible (orange rectangles in the figures) that the window is made narrower. Changing the Mask width will shift the Lead angle and causes distortion of the current waveform, so change Lead angle again (iterative process).

PWM Duty[%]	Lead Angle =LASET_L =LASET_H	MSK0	MSK1	rpm
30	7	11	2	1400

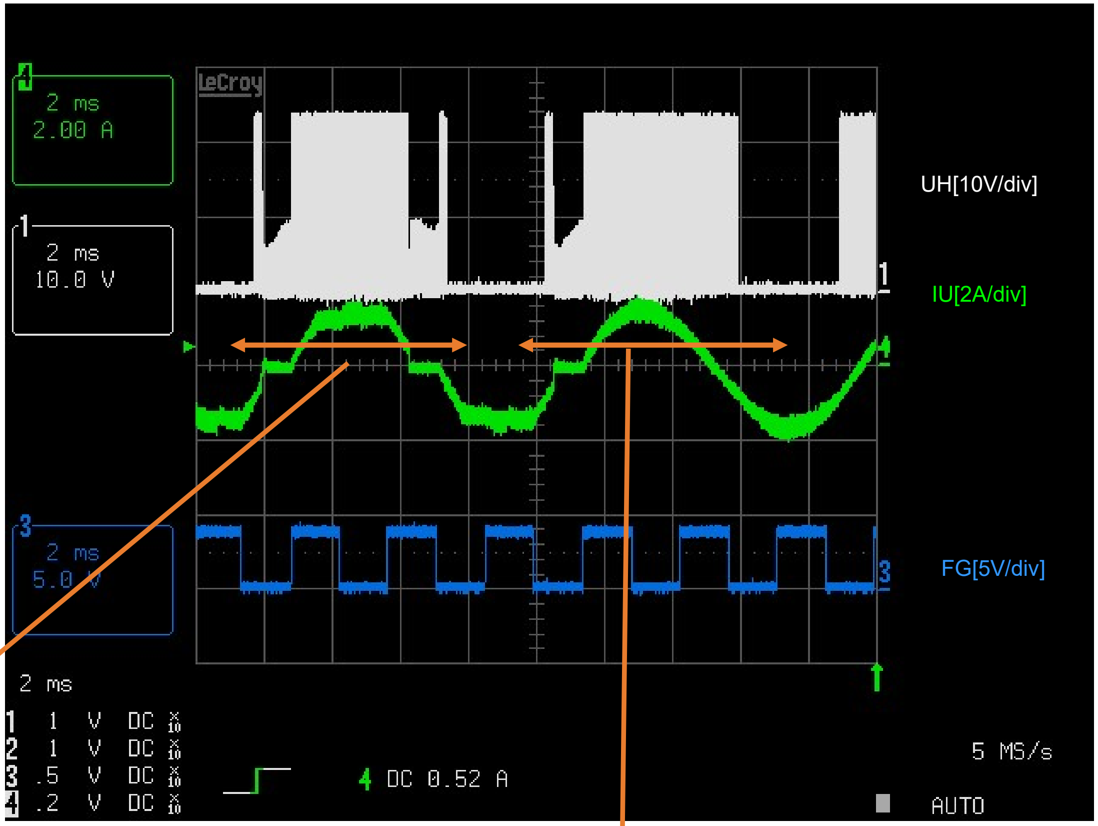
Step 3) Stability and Recovery Mode

- If the measurement window is too small, LV8961H will switch to 6 window recovery mode. This can be seen by large measurement windows opening up in all phases (A).
- Reduce both MSKRSTNUM0 and MSKRSTNUM1 to reach stable mode (B).

Remember the window size is:

60deg – (MSKRSTNUM0 + MSKRSTNUM1)

... and must be positive.



A) When the window narrows and BEMF can not be detected, stable operation is possible only in 6-window mode.

B) stable 1-window mode

Best Fit determination for Sinusoidal Mode

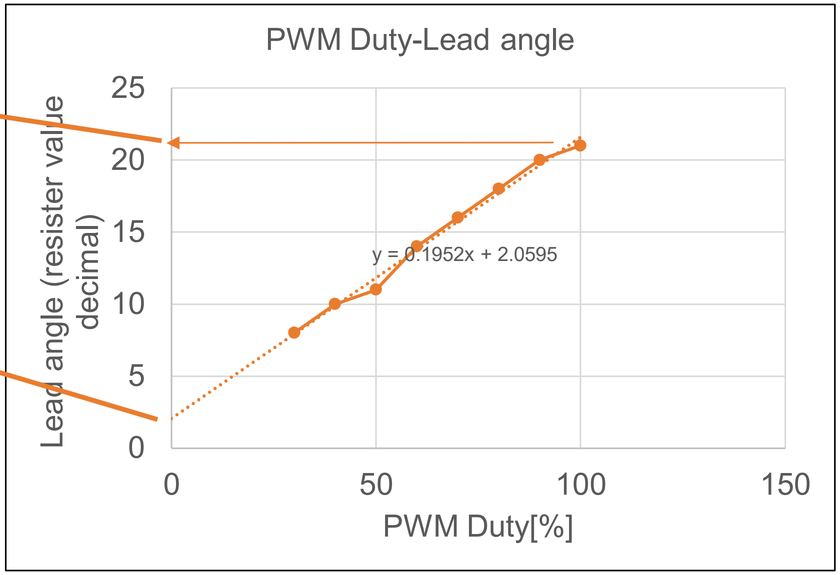
1. After filling the table up to 100% duty cycle copy the widest mask setting into all mask fields.
2. Set these values in MASK0 and MASK1.
3. With these mask values, perform the lead angle optimization again.
4. Do a linear fit over the lead angle values vs. duty cycle.
5. Enter the min and max lead angles in LASET_L and LASET_H.

PWM Duty[%]	Lead Angle =LASET_L =LASET_H	MSK0	MSK1	rpm
30	7	11	2	1400
40	8	11	3	1780
50	10	9	3	2200
60	12	8	3	2450
70	16	7	4	2750
80	18	7	4	2950
90	20	7	4	3150
100	21	7	4	3350

PWM Duty[%]	Lead Angle =LASET_L =LASET_H	MSK0	MSK1	rpm
30	8	7	4	1400
40	10	7	4	1780
50	11	7	4	2200
60	14	7	4	2450
70	16	7	4	2750
80	18	7	4	2950
90	20	7	4	3150
100	21	7	4	3350

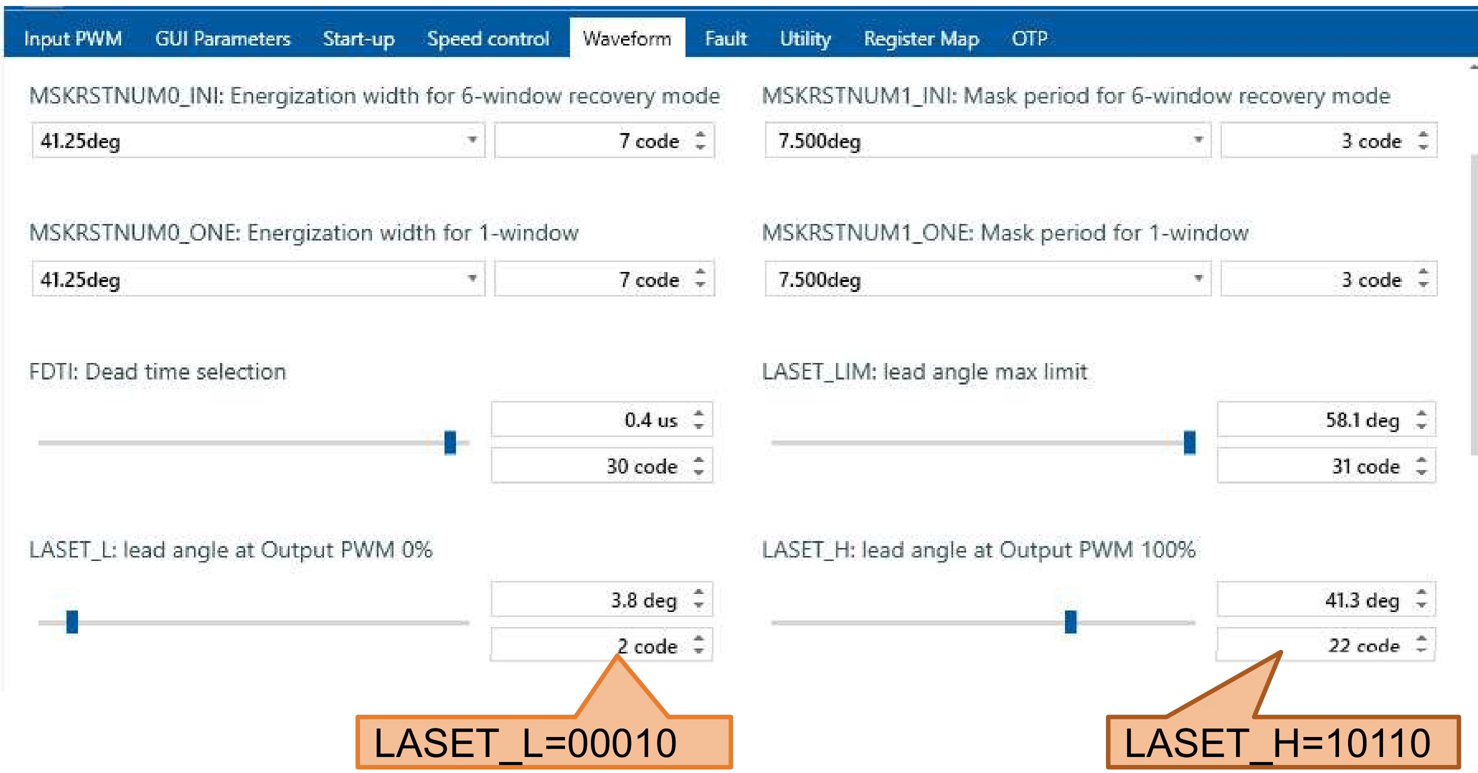
Lead angle(LASET_H) is 22 at PWM Duty 100%

Lead angle(LASET_L) is 2 at PWM Duty 0%



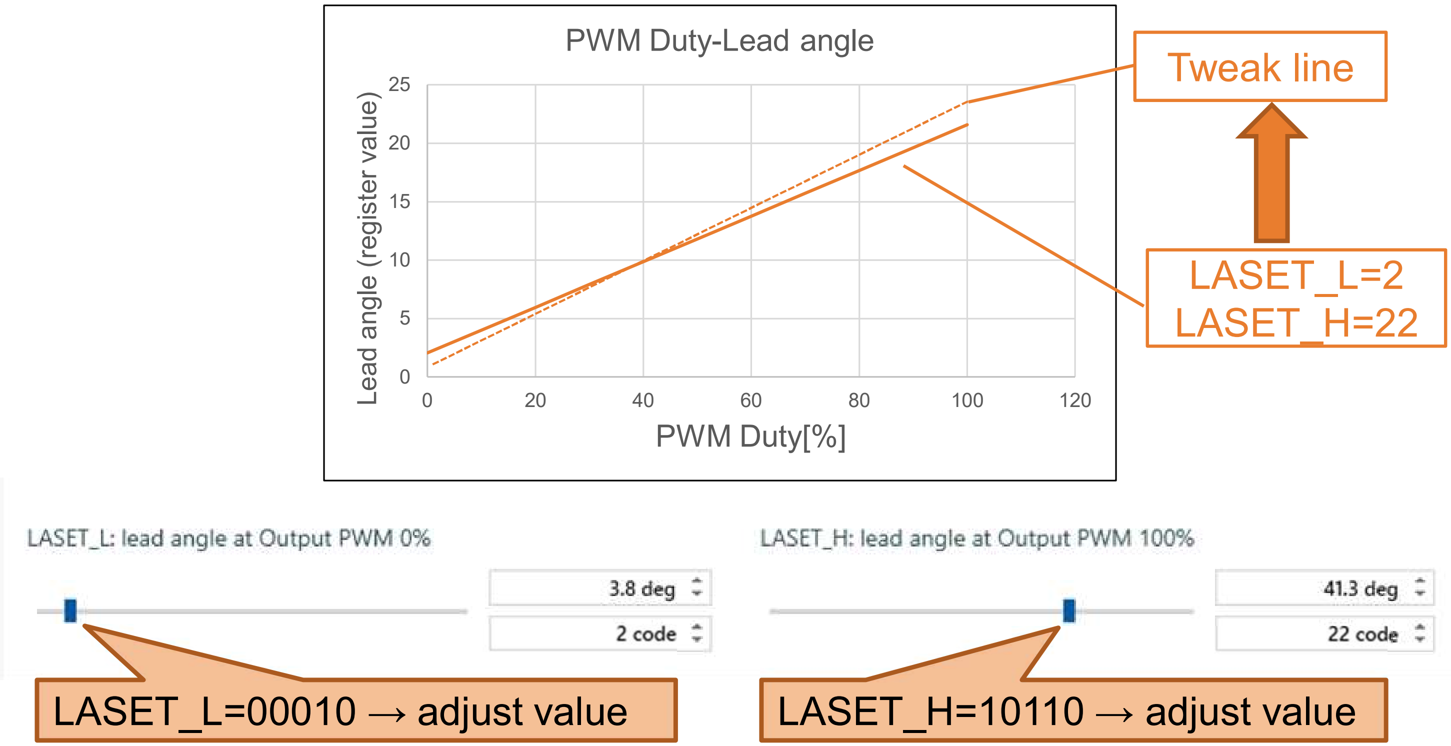
Final Verification

With LASET_LIM at maximum, enter Lead angle from the previous example =(2d)= (00010b) with PWM Duty = 0% in LASET_L. Enter Lead angle =22d= (10110b) with PWM Duty = 100% in LASET_H. Check if stable operation is performed under the conditions from the minimum rotation speed to the maximum rotation speed.



Some last tuning

If the motor did not rotate with the settings on the previous page, fine-tune (±1bit) the lead angle settings (LASET_L, LASET_H) based on the interpolation and check the motor stability again.



The End

Thank you for your attention !