USB-MC Motion Controller and THC Mode of Operation

THC (torch height control) function is used with plasma cutter systems for continual regulation of torch height i.e. for keeping a constant distance from the torch to work material. The most common way to maintain the correct cutting height is by monitoring the arc voltage and adjusting the torch height to keep this voltage constant at the predefined desired value. This is because the torch voltage is directly proportional to the arc length i.e. distance from the material. A good regulation is essential for maintaining correct high and consistent quality of the cut.

Main features that USB-MC motion controller brings:

- **Two options for THC regulation:**
  - support for external THC regulators,
  - integrated THC classic Up/Down regulator (1 ms response).
- **Advanced options for internal THC regulator:**
  - kerf detect - tip saver,
  - lock THC motion when arc voltage goes out of specified valid range,
  - arc presence detection,
  - arc voltage sampling frequency of 1 kHz,
  - adjustable voltage low pass filter.
- **For both integrated and external regulator mode:**
  - THC enable/disable using G-code commands,
  - Anti-plunge option,
  - Manual THC mode.
- **Customized Mach3 screen** with additional indicators and DRO fields.

Traditionally with Mach3, external THC regulator is used that measures arc voltage and via digital inputs on LPT port it issues requests to Mach3 to move the plasma torch up or down.
When using USB-MC motion controller in external controller mode, THC operation is almost identical to traditional Mach3 routine working with LPT port driver.

A new option that USB-MC motion controller brings is the integrated THC controller that can be utilized by connecting a voltage sensor to the analog input of USB-MC motion controller. Internal THC controller also brings advanced options to control THC like kerf detect (tip saver). For both regulators it is possible to control (enable/disable) THC motion using commands from G-code and also to take manual control by using manual THC mode.

It should be noted that full version of Mach3 is required for THC operation (demo version does not support THC mode of operation).

In both cases, regardless whether internal or external regulator is used, all important functions are performed autonomously in hardware of USB-MC motion controller so that fast regulator reaction is guaranteed.

In order to display THC specific controls on Mach3 main screen, it is required to either chose some plasma profile when starting Mach3 (like supplied Plasma.xml) or to load "plasma.set" screen to any existing profile using menu option "View/Load screens...".

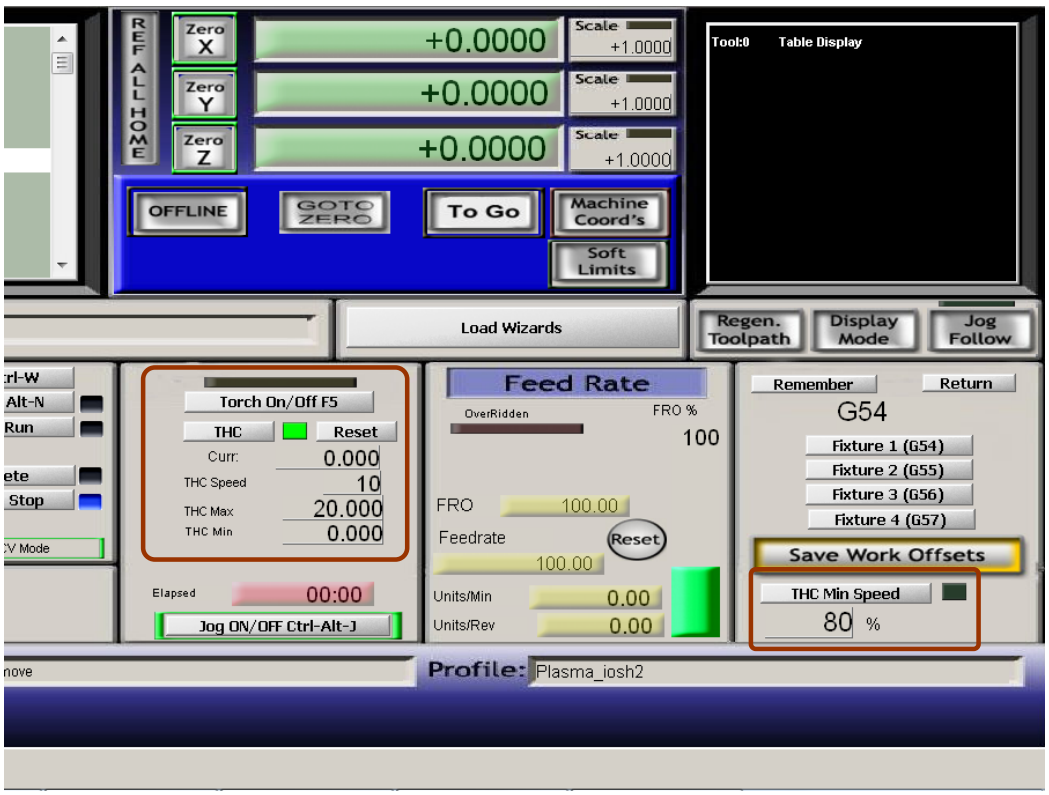

Figure 1 THC controls on Mach3 "Plasma.set" screen

Short description of THC controls:

- Torch On/Off – button can be used to manually turn torch on/off. Usually this button is not used except for testing purposes, and the torch is controlled programmatically by G-code commands, usually M3 is used to turn torch on and M5 to turn it off.
- THC – turns on/off THC mode of operation. **THC mode must be turned on manually before the beginning of work so that USB-MC motion controller could correctly execute THC functions.** LED indicator near the button shows whether this mode is active (green rectangle).
- Reset button – resets to zero internal variable (Curr: field) that represents correction of vertical position (z axis) of the plasma torch. Current *z* position of the torch then becomes reference point for defined minimum and maximum of *z* correction.
- Curr field – displays current value of *z* position correction. At the moment of torch ignition, current *z* position is remembered as a reference, so THC Max and THC Min are defined in relation to this reference.
- THC Speed – field is used to specify vertical movement speed of plasma torch when regulation is performed. It is given as a percentage of the maximum speed of z axis that is defined in motor tuning adjustments. **Similarly to operation via LPT port/driver, because of need for fast regulator reaction, Up/Down THC moves does not feature ramping acceleration and deceleration. Therefore this speed should be set carefully to appropriate lower value that will not cause step motor to stall**.
- THC Min / THC Max – fields define minimum and maximum correction for z position of plasma torch in relation to the reference position.
- THC min speed – button enables anti-plunge option that prevents plasma torch from falling too low. This can happen if during cutting motion velocity in *x-y* plane drops significantly, for example at sharp corners of cutting contours, i.e. on rapid changes of moving direction. THC min speed is specified as a percentage of set feedrate. If speed in *x-y* plane drops below this value, Up/Down THC commands are ignored until speed rises again.

WARNING: It is recommended to avoid simultaneous z axis control by G-code and by THC Up/Down regulator, internal or external (when ARC_OK signal is active). USB-MC motion controller will in this case favor G-code z axis movement while Up/Down requests from THC regulator will be suspended. Nevertheless, because of sudden changes of motion type also motion speed and direction, stall of stepper motor that controls z axis is possible.

Therefore it is advisable to correctly define a time period USB-MC THC options/ Pierce delay (figure 6) so that all G-code controlled movement of z axis is finished before enabling regulation performed by internal or external THC regulator.

Alternatively it is possible to specify appropriate pause time in external controller if it supports such an option. THC controllers usually offer the option to specify pause time from the torch ignition to the activation of Up/Down commands in order to prevent sudden drop of plasma torch head toward the material just after torch ignition. Namely, it is necessary to wait for arc voltage to fall to a normal value and stabilize.

Figure 2 shows one possible procedure for initial positioning of the plasma torch and the arc ignition. It can be seen that in the beginning period a G-code movement along z axis is performed, first to position for the arc ignition, and then after the pierce, for the actual cutting. When this later positioning is finished, and after pierce_delay time delay has elapsed, Up/Down movements from THC regulator are enabled.

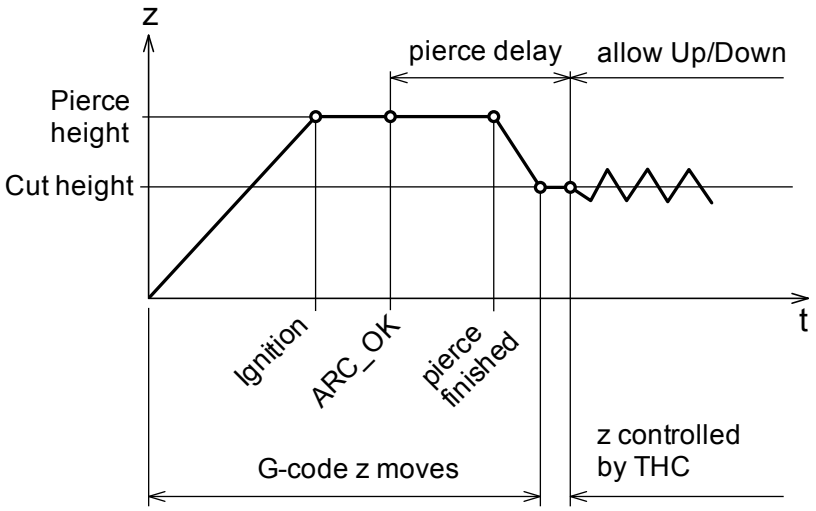

Figure 2 Example of plasma cutter operation

Ignition of the arc is initiated usually using M3 command which, for example, activates Output #1 signal that is connected to the plasma inverter.

ARC_OK (THC on) signal is sourced from the plasma inverter (or from external/internal THC controller) and indicates presence of the arc. Mach3 waits for this signal to continue program execution after arc ignition is commanded. If arc is lost at some time, then all movement is suspended until arc presence is detected again.

Figure 2 does not show initial search for the material i.e. zero z position. That function can be realized using PROBE or HOME G-code commands and for this it is required that machine supports some means to detect contact between the plasma torch and the material (floating head or ohmic sensor).

Configuration for operation with external THC regulator

For operation with external THC regulator it is required to setup port and pins for digital inputs THC On (ARC_OK), THC Up, THC Down (figure 3).

THC On – signal name may be confusingly formulated and really means ARC_OK i.e. working arc is detected. This signal can be sourced from plasma inverter, external THC controller or a special current sensor installed for the purpose of arc detection.

Alternatively, it is possible to completely avoid usage of this ARC_OK signal and in that case it is required to open Mach3 dialog box Config/Ports and Pins/Mill Options and in THC options group to turn on the option Allow THC UP/DOWN Control even if not in THC mode.

In that way Mach3 is instructed not to wait for the ARC_OK signal when executing G-code, so after M3 command for the arc ignition, execution does not pause but instead it is continued immediately.

In other words, **if internal/external detection of ARC_OK signal is used then this option should be turned off** (Allow THC UP/DOWN Control even if not in THC mode).

THC Up – command to move plasma torch up.

THC Down – command to move plasma torch down.
In addition, it is necessary to set up digital output that is used for the arc ignition that is controlled by command M3/M4. In example that is shown on figure 4, Output#1 has been chosen and for that signal, port and pin number has been set (figure 5).

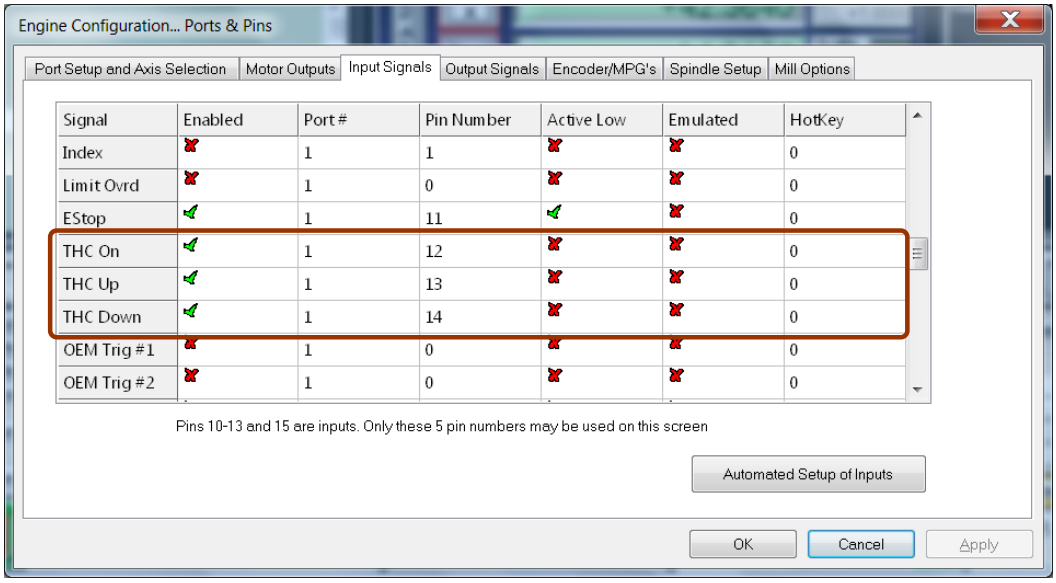

Figure 3 Configuration of THC input pins
NOTE: This example shows pin setup when using USB-UIO1 card and opto-isolated inputs DIN 6-8.
For other cases of input-output hardware it is necessary to adjust pin numbers.

Optionally it is possible to set delay times that are introduced upon the torch turn on/off, shown in General parameters group on figure 4. **This settings apply also to the internal regulator**.

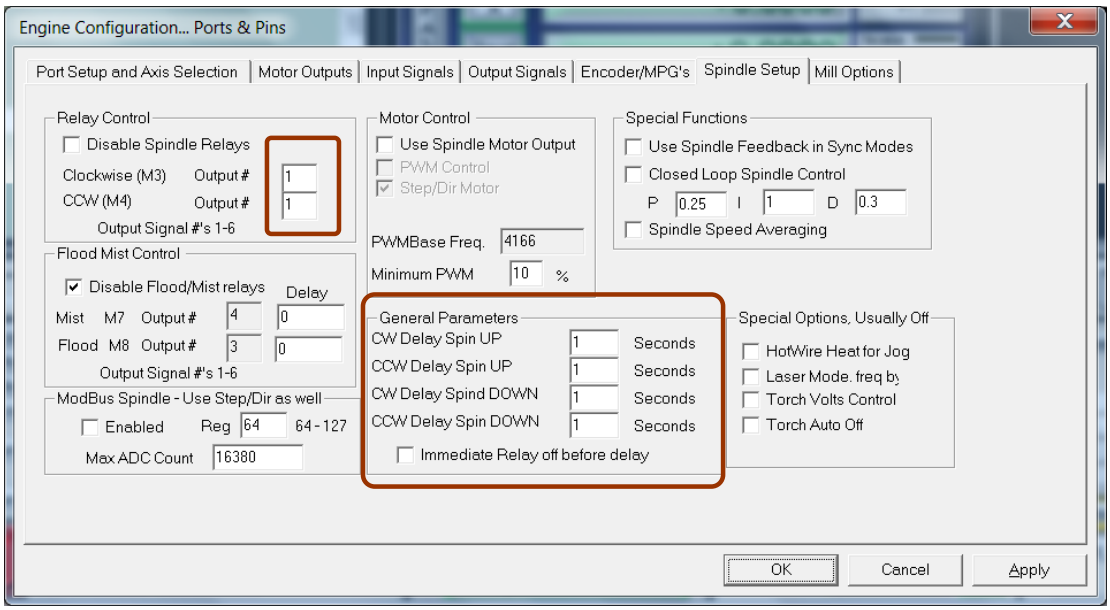

Figure 4 Setting up digital output signal for ignition of the plasma torch

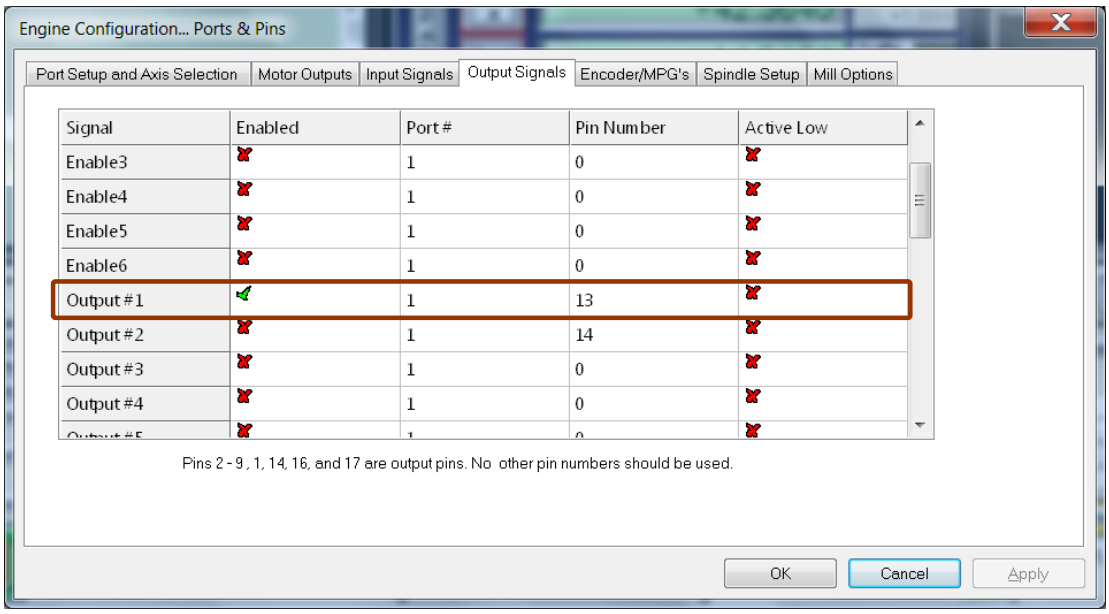

Figure 5 Setting up output pin for plasma torch ignition signal
NOTE: This example shows pin setup when using USB-UIO1 card and relay 1.
For other cases of input-output hardware it is necessary to adjust pin number.

In USB-MC configuration dialog that can be opened using menu option Plugin Control/USB-MC Config.../THC options (Figure 6) for THC type it is needed to select option External THC.

For both regulator types (internal and external) the following two options are available to setup:

Pierce delay - As already mentioned, this field defines the time delay from the moment when ARC_OK signal is detected to the moment of enabling Up/Down motion requested from THC regulator.

Usually M3 command for arc ignition is followed by G04 command that is used to wait for the pierce to be completed. After that, torch is positioned to cut height and cutting operation (moving in x-y plane) begins. Pierce delay parameter should be set so that THC motion is enabled only when all this mentioned steps are completed (Figure 2).

Force wait for THC_ON after M3 (fix Mach3 bug) - Mach3 has a bug (or at least illogical feature) regarding the order of operations after execution of M3 command for the arc ignition. Namely, as already mentioned, often after M3 command then follows G04 command for waiting to material pierce to be completed before continuing further code execution.

So, correct order of steps should be:

- execute M3 command,
- wait for ARC_OK signal,
- pause for G04 dwell time,
- continue execution.

How Mach3 really works:

- execute M3 command,
- immediately execute G04 dwell pause,
- wait for ARC_OK signal,
- continue execution.

The difference often goes unnoticed if after M3 is executed torch gets ignited very fast while dwell pause time is still in progress. But, if torch ignition takes longer so that ARC_OK signal appears later after the dwell pause, Mach3 then continues operation without any delay. Also, time needed for torch to ignite can vary (especially is longer for the first ignition), thus it is desirable for pierce pause (given via G04) to be measured from the moment of ARC_OK signal appearance.

To get over this problem an option is introduced to force waiting for ARC_OK signal first after M3 command issuance and only then continue further operation. This way the correct order of steps is achieved and also more precise timing for torch ignition sequence is achieved.

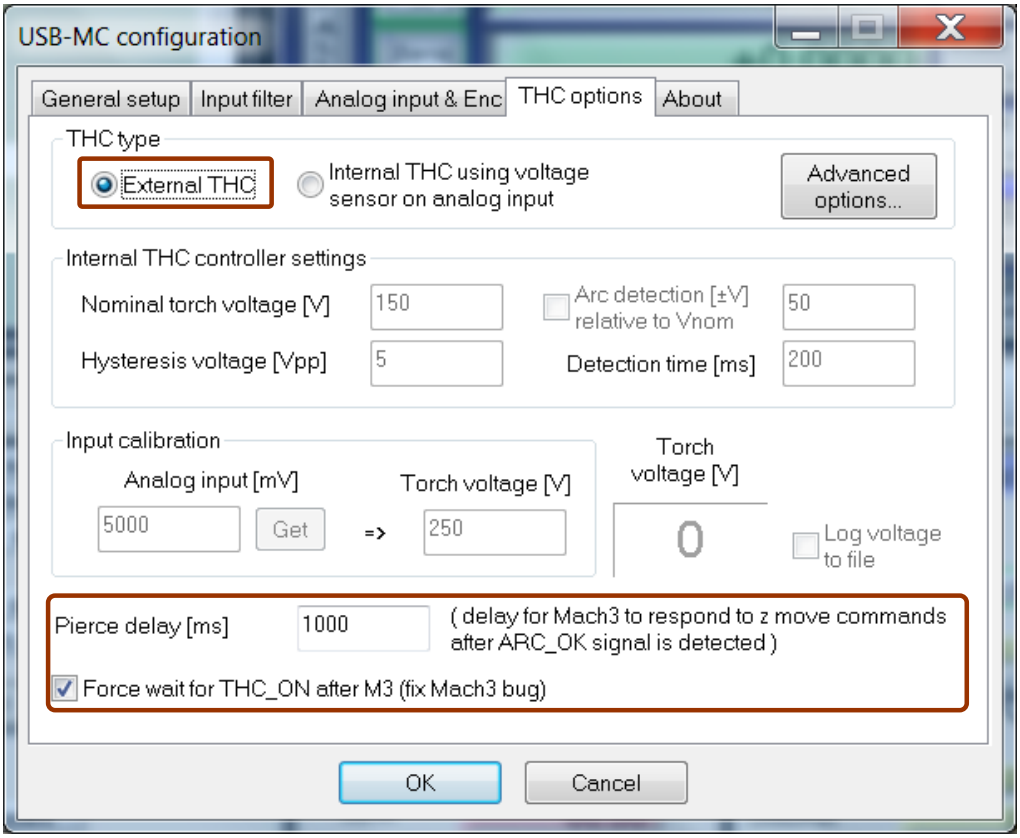

Figure 6 USB-MC dialog for configuring options when working with external THC regulator

Configuring the internal THC regulator

The THC regulator integrated in USB-MC motion controller replaces the function of external regulator and it is realized completely in hardware. For this function it is necessary to connect voltage signal from plasma inverter via special isolated interface to the analog input of USB-MC motion controller.

NOTE: **More about THC Sensor can be found on website www.audiohms.com**

THC type – it is required to select option Internal THC using voltage sensor on analog input (as shown in Figure 7)

Nominal torch voltage [V] – desired arc voltage i.e. nominal voltage value

Hysteresis voltage [Vpp] – voltage hysteresis, peak-to-peak

Arc detection [±V] relative to Vnom – option for arc presence detection (activates ARC_OK signal) that works by monitoring the arc voltage. The first parameter that should be specified is voltage margin in positive and negative directions in relation to the nominal value (Vd on figure 8), and second parameter Detection time (Td), is time interval for the detection. Namely, it is required for the arc voltage to stay during this defined time period inside given voltage range to consider that arc is established and ARC_OK signal is then activated.

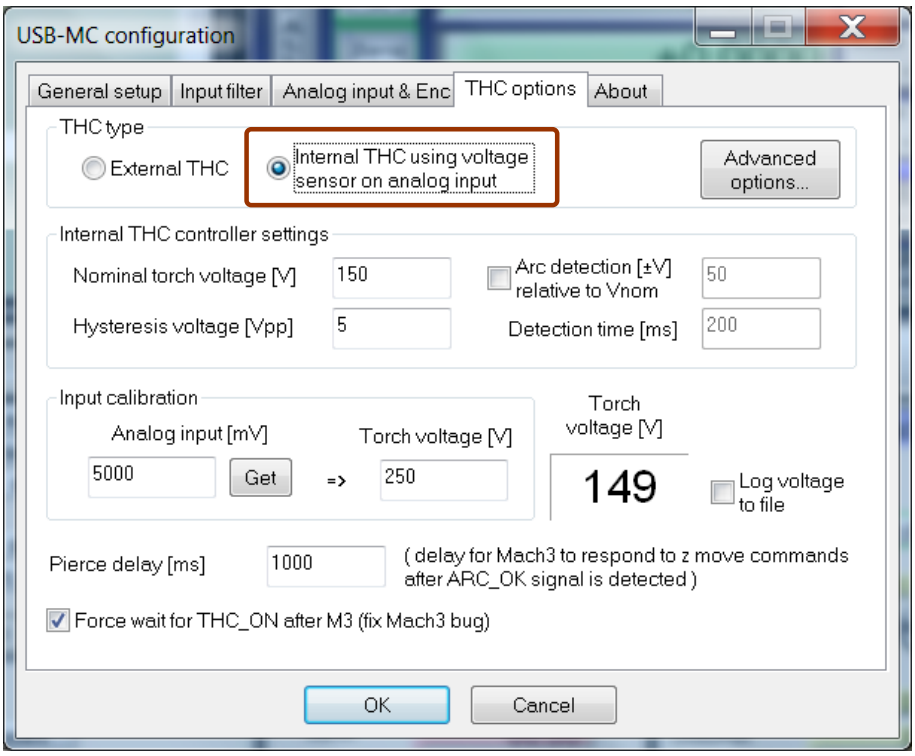

Figure 7 USB-MC dialog for configuring THC options when working with internal THC regulator

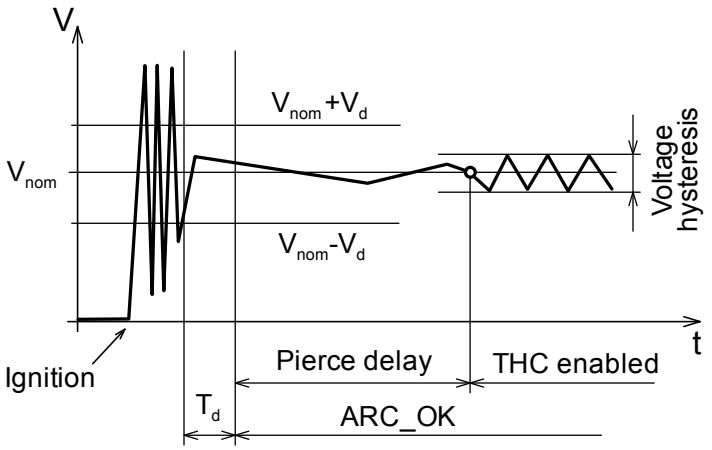

Figure 8 Plasma torch arc detection procedure

This option is useful if there is no possibility of bringing in an external ARC_OK signal and **in that case it is needed to turn off THC_ON signal in Ports&Pins settings (Figure 3) because ARC_OK signal is internally generated.**

On the other hand, if that possibility exists, it is required to setup digital input for this signal in the same way like when using external THC regulator (Figure 3).

NOTE: As already mentioned in external regulator section, it is possible to completely avoid usage of this ARC_OK signal and in that case it is required to open Mach3 dialog box Config/Ports and Pins/Mill Options and in THC options group to turn on the option Allow THC UP/DOWN Control even if not in THC mode. **In that way Mach3 is instructed not to wait for the ARC_OK signal when executing G-code, so after M3 command for the arc ignition, execution does not pause but instead it is continued immediately.**
In other words, **if internal/external detection of ARC_OK signal is used then this option should be turned off** (Allow THC UP/DOWN Control even if not in THC mode).

Input calibration

Interface that is used to connect plasma system to USB-MC motion controller has a certain voltage transfer ratio, i.e. high voltage that is present on plasma system side is downscaled to a voltage level that is appropriate for reading by USB-MC motion controller. This transfer ratio (voltage divider) is 50:1 on Audiohms plasma interface (optionally 1:1). THC sensor appearance is shown on figure 9.

Figure 9 THC Sensor

So, to ensure correct calculation of arc voltage from a voltage reading on the analog input, it is necessary to perform a calibration. That can be done by providing one pair of values input-output. Transfer ratio 50:1 is related to default setting: 5000mV–250V.

Some plasma inverters have integrated voltage divider feature so that they offer lower voltage output signal (usually 0-5V) that is proportional to the plasma arc voltage. In that case it is possible to utilize voltage input 1:1 that is located on THC sensor (figure 9).

Field Torch voltage [V] on the right side should, after the calibration, shows the correct value of current arc voltage.

Analog input [mV] – voltage value read from the analog input. Maximum is 5V. This field can be populated manually or by pressing Get button in which case a current voltage value read from the analog input is taken.

Torch voltage [V] – plasma arc voltage that corresponds to previously specified voltage on the analog input.

Regarding the Ports & Pins dialog settings (figure 3), digital inputs THC Up and THC Down signals must be turned off as these signals are generated internally. Also, if option for internal detection of plasma arc is enabled, the input signal THC On should be turned off as well.

Digital output that initiates plasma torch ignition is setup the same way like it is done when using external controller (figures 4 and 5).

Also, as already mentioned, options Pierce Delay and Force wait for THC_ON after M3 (fix Mach3 bug) also apply to the internal regulator (these options are explained in external regulator section of this setup guide).

NOTE: For proper wiring of plasma system to USB-MC motion controller via plasma isolation interface please consult documentation for this interface.

Advanced THC options

First three options (Figure 10) are related to monitoring the torch voltage thus they are only available when using analog THC sensor and internal regulator.

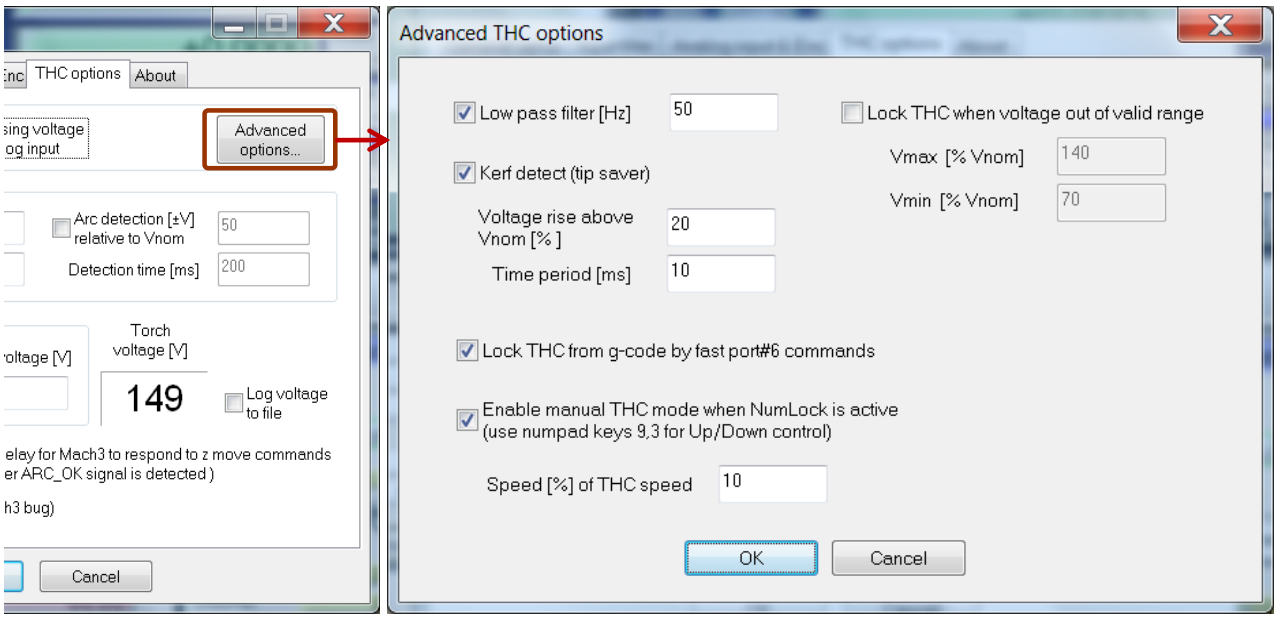

Figure 10 Advanced THC options

- Low pass filter [Hz] – Arc voltage signal that is monitored by THC controller can have a considerable noise present. Analog sensor (Figure 9) has embedded filter for noise suppression, but further filtering may be needed.
  Low pass filter is used to suppress frequencies above specified frequency. Lower this filter frequency is specified, better will be noise suppression, but at the same time bigger is slowdown of regulator reaction to the real signal changes.

- Kerf detect (tip saver) – When torch head crosses already cut path (kerf) or any other void in material, when crossing the void arc is lengthened, sparsed and is closed via near-by material edges. That leads to arc voltage rise, so THC controller reacts by lowering the torch and in worst case torch head can crash in the material.
  To prevent this problem an option is introduced to detect kerf crossing and to disable THC movements during the crossing time. THC movement is allowed again only when torch voltage drops to a normal value.
  Kerf detection works by monitoring the arc voltage and is looking for the fast voltage rise.

  Parameters to specify:
  - - Voltage rise above Vnom [%] – Arc voltage rise above specified nominal value (in percent). If lower value is given (like few %) detection sensitivity is higher, but false detection can happed because of the present noise or other normal voltage variations. On the other hand, if too high value is specified, kerf may not be detected or may not be detected fast enough.

  - Time period [ms] – detection time period. Voltage rise must be fast enough to happen inside this time period to be detected as kerf crossing. In other words, if lower value is specified for time period (for example 5 ms), and voltage change (rise) is slow, then in this case this will not be recognized as kerf crossing.

    It should be noted that Low pass filter if enabled (previous option described) suppresses fast voltage changes when filter frequency is set lower. In that case for kerf detection to work properly it is needed to enlarge detection time or to specify higher filter frequency.

- Lock THC when voltage out of valid range – this option is used to disable THC movements if arc voltage is out of range. That can happen as mentioned when crossing kerf or other void in work material or for example when torch is moved out of the material bounds

  Parameters to specify:
  - Vmax [%Vnom] – upper arc voltage limit as a percent of the nominal voltage,
  - Vmin [%Vnom] – lower arc voltage limit as a percent of the nominal voltage.

- Lock THC from G-code by fast port#6 commands – it is often desirable to temporarily disable THC movements by commands from G-code. Examples for this are for instance when cutting small holes, when during the cutting, pieces of the material drop down and leave a void, also when cutting traces with sharp corners where movement in X-Y plane is slowed down and that leads to lowering of the plasma torch etc.

  For this purpose are chosen the fast commands for output port control (originally intended for laser applications). This control type has a few good properties: commands are fast so there is no delay in execution, continuity of CV movement is preserved so these commands can be issued in the middle of cut trace and are ideally synchronized with G-code axes movements.

  When this option is enabled, fast commands for port 6 control are interpreted as THC movement lock or unlock commands. Signal Output#6, namely corresponding port and pin in Mach3 settings (Ports & Pins) **does not need to be setup** for this commands to work properly.

  Specifically, commands are:
  E6p1 (disable THC motion)
  E6p0 (enable THC motion)

  Popular CAM programs that are used for plasma cutting support generating THC enable/disable commands in G-code according to previously defined criteria.

  This option works with both THC controllers, internal and external.

  NOTICE:

  It should be reminded about the feature of these fast port commands that, strictly speaking, **they are executed at the start of next G-code motion in the program**. For example, if G-code similar to this everything is clear:

```
G1X100
E6P1
G1X200
```

  But in the following G-code program THC motion will be disabled only at fourth program line which is not obvious at first glance:

```
G1X100
E6P1
G04 P1
G1X200
```

  Nevertheless, when this kind of behavior is not desirable it can easily be overcame by inserting any kind of motion of any axis just after command E6P1 in this case.

- Enable manual THC mode when NumLock is active – this option enables manual THC mode that is used for manual control of the plasma torch height.

  Namely, regardless of selected THC regulator, sometimes it is useful to temporarily take manual control. This may be the case for example for experimental determination of optimal height of the plasma torch during the cutting process. Manual mode can be activated at any time by pressing the NumLock key on numeric pad part of the keyboard. During the time while manual mode is active, THC automatic control is suspended and torch head can be moved up or down by pressing keys 9 and 3 on numeric part of the keyboard.

  By pressing NumLock key again, manual THC mode is deactivated and automatic regulation takes over control over the torch height.

  In manual mode, motion control is enabled even if there is currently active THC lock by some of the lock related THC options, and also the presence of the arc does not have to be detected.

- Speed [%] of THC speed – this field enables specifying the speed of movement in manual THC mode. Speed is given as a percent of the specified THC speed (field THC Speed on Mach3 main screen).

Custom plasma screen set

For a more comprehensive display of options and status indicators that are used in THC mode with USB-MC motion controller, it is possible to load a custom made screen set. This screen is a modified version of the original Mach3 Plasma.set screen.

Five new LED indicators (ArcOK, Up, Down, Lock, Manual) have been added to the main plasma control group, and they show current state of corresponding signals and modes of operation (figure 11). Lock indicator is active when THC motion is disabled (during pierce delay pause, during anti-dive or by advanced options kerf detect, voltage out of valid range, or from G-code by appropriate commands).

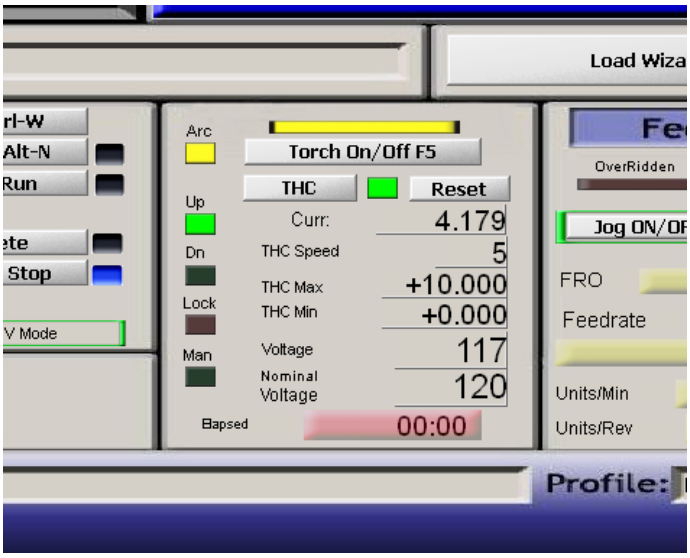

Figure 11 Mach3 screen set customized for THC mode when using USB-MC motion controller

Manual THC mode indicator flashes when this mode is active.

Also added are the fields that display current and nominal value of the torch voltage. These two fields are specific for the internal THC regulator of USB-MC motion controller. Nominal voltage can be specified by directly editing this field (in addition to using THC dialog of USB-MC motion controller shown on Figure 7).

Sometimes it is necessary to enter a negative value in the field THC Min, and that is not possible when using the original plasma.set screen. In this modified version that also has been enabled.

Custom screen set is available for download from www.audiohms.com site on the page that describes USB-MC motion controller.

Practical considerations and examples of THC cutting

Searching for material

This procedure is not specific to USB-MC motion controller, i.e. it is the same as when working with parallel port, but it is given here for completeness of the manual.

Searching for material, i.e. adjusting initial z position before the arc ignition, can be performed in two ways:

- using probe function (G31)
- using home (G28.1) function of Mach3

If G31 method is used, it is needed to setup floating head as Probe input signal in Ports&Pins settings of Mach3, and then CAM postprocessor should generate a G-code like this:

```
G31 Z-100 F50    (probing downwards with speed 50 mm/min)
G92 Z-0.1        (set current position as Z=-0.1)
G00 Z5.0         (continue work, go to arc ignition height)
```

In case that G28.1 method is used, it is needed to setup z axis homing to be performed downwards and floating head should be setup to generate home signal for z axis (acting as a home switch).

In that case CAM postprocessor should generate G-code like this:

```
G28.1 Z0.50      (homing Z axis via point Z=0.5)
G92 Z-0.1        (set Z=-0.1)
G00 Z5.0         (continue work)
```

Example G-code for plasma cutting using THC

```
G0 X0Y50         (go to appropriate X,Y position)
G31 Z-100 F50    (probing downwards with speed 50 mm/min)
G92 Z-0.1        (adjust Z offset so that current position becomes Z=-0.1)
G0 Z5.0          (go to Z height for the arc ignition)
M3               (command for the arc ignition, Mach3 waits for ARC_OK to
continue execution)
G4 P0.5          (dwell time 0.5s, wait for material pierce to complete)
G0 Z2.0          (go to cut height)
F1000            (feedrate = 1000 mm/min)
G2 X100 Y50 R50 (cutting the first part of the circle; when elapses pierce_delay
time that is measured from the moment of ARC_OK signal appearance, then THC
Up/Down regulation is enabled)
G2 X0 Y50 R50    (cutting second part of the circle)
M5               (turn off the arc)
M30              (end of program)
```

In the first part of the code searching for material is performed using G31 method, then torch is moved to ignition height. After M3 command for arc ignition, appearance of ARC_OK signal is waited (it is recommended to turn on option Force wait for THC_ON after M3 (fix Mach3 bug) in THC options of USB-MC motion controller).

When ARC_OK signal is recognized Mach3 continues execution of G-code and next command is G4 i.e. pause for 0.5s until material pierce is completed. At the same time, from the moment when ARC_OK signal is recognized, pierce delay time elapses (time delay to enable THC up/down regulation). This time period should be adjusted so that THC regulation is enabled only after pierce of material is completed and cutting of the material has been stared.

Manual control of plasma torch height by using emulated inputs

Sometimes it is useful to manually (using keyboard keys) control up/down motion of the plasma torch. Besides the manual THC mode offered by USB-MC controller, this is also possible to realize by using emulated inputs.

Mach3 offers a possibility for input signals (including also THC Up and THC Down) to be emulated by keyboard. These signals should be selected as Emulated and assigned a keys (HotKey) for manual control (Figure 3).

For this simulated control to work, THC function requires that:

- in USB-MC configuration (Figure 6) for THC type it is selected External THC mode because otherwise, if internal THC regulator is active, signals Up/Down are generated internally,
- THC mode is turned on (using THC button on the main screen),
- arc ignition is initiated either manually clicking the button Torch On/Off F5 or by M3 command from G-code,
- ARC_OK (THC_ON) input signal is detected. After this signal is activated, defined time period (pierce delay) is waited and then Up/Down motion is enabled.

Alternatively, if this signal is not used, it is necessary to turn on option Menu/Config/PortsAndPins/MillOptions/Allow THC UP/DOWN Control even... In that case, right after the arc ignition is initiated, it is considered that arc is present and no further waiting for the arc is performed.

- Turned off the option THC Min Speed on the main screen in the lower right corner (Figure 1). This option (so called anti-dive) is used to disable THC regulation when feedrate in x-y plane drops bellow certain specified speed (set as a percent of maximum speed). So, to enable THC Up/Down motion also in the still state, it is needed to turn this option off.

Frequently asked questions

- ***THC regulation works, but constant up-down motion in regular rhythm is present, why is this happening?***
  This is regulator oscillation that can happen if too high speed of THC motion is specified (THC Speed) or, when using internal regulator, too small voltage hysteresis (difference between maximum and minimum voltage) is specified.

- ***ARC_OK signal is activated right after M3 command for the arc ignition is executed, instead of waiting for the real recognition of this input signal***.
  Option Menu/Config/PortsAndPins/MillOptions/Allow THC UP/DOWN Control even not in THC mode... is turned on. This option, as the matter of fact, is indeed used to avoid usage of ARC_OK signal.

- ***THC regulator does not react on occurrence of some of the input signals (Up, Down, THC On/ARC_OK).***
  It should be verified that inputs in Ports&Pins settings are properly setup, also that option Emulated is not selected for that signals.

- ***Mach3 during the G-code execution after the arc ignition by M3 command, does not correctly wait specified G04 dwell pause time.***
  It is needed to turn on the option Force wait for THC_ON after M3 (fix Mach3 bug) on USB-MC THC configuration dialog.
  Also check if time is given in seconds or milliseconds, i.e. according to the setting in Mach3 (Menu/GeneralConfig/G04 Dwell in ms).

- ***Z axis motion range is limited and is insufficient for proper THC regulation***.
  It is needed to correctly setup fields THC Min and THC Max on Mach3 main screen. Also check if specified SoftLimts for Z axis are limiting the movement range. Furthermore, it is possible that Z axis is not properly calibrated, so check in Menu/Config/MotorTuning dialog whether field steps per unit is set to a correct value.

DOCUMENT REVISION:

- Ver. 1.0, November 2017, Initial version
- Ver. 1.5, November 2018, Added “Advanced THC options” and “Frequently asked questions”
- Ver. 1.7, March 2019, Added option “Enable manual THC mode when NumLock is active”
- Ver. 1.71, December 2020, Minor revision
- Ver. 1.71, August 2021, Minor revision