



ST92141 AC MOTOR CONTROL SOFTWARE LIBRARY
VERSION 2.1 UPDATE

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This application note provides information on release 2.1.1 of the ST92141 AC motor control firmware. The corresponding software package is available on internet at:
<http://www.st.com/stonline/products/support/mcu8/mc/st92141.htm#soft>.

1 WHAT'S NEW IN ST92141 SOFTWARE LIBRARY V2.1 COMPARED TO V2.0

- The Sine-wave generation routines have been enhanced to allow sinusoidal PWM with third harmonic injection. This optimizes the DC bus voltage use, allowing to get-up to 15% more voltage on motor windings without current distortion.
- The V2.1 library can now be compiled using V6.x Software Toolchain.

2 FIXED BUGS AND ENHANCEMENTS

- The IMC_InitTachoMeasure function has been enhanced: it can now be called anywhere in the user program: the previously missing spp() instruction has been added before the IMC hardware register accesses.
- The ACM_Update_Sine_Tables function has been modified: frequency limitation at high speed is now functional.
- Default parameters for Voltage vs Frequency and Slip vs Frequency curves have been updated.
- Interrupt service routine prototypes have been added in corresponding.c files (warning messages generated otherwise).
- Cleaner C coding of several functions by appropriate casting of variables.

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3 SINUSOIDAL PWM WITH THIRD HARMONIC INJECTION

3.1 PRINCIPLE OF OPERATION

In the previous releases of the AC motor control software libraries, the reference PWM modulating signal was a pure sinewave (Figure 1. left). This kind of modulation has the drawback that it makes poor usage of the DC bus voltage.

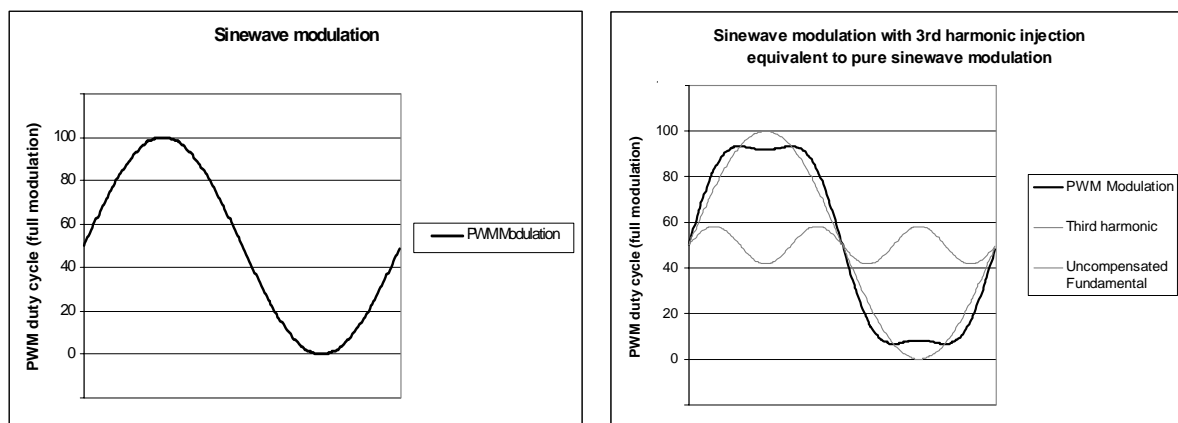
Let's consider V_{bus} as the bus voltage after mains rectification. One can easily find that maximum available voltage on a motor using a standard three-phase power inverter is around 86% of V_{bus} .

$$V_{phase-neutral} = \frac{V_{bus}}{2} \text{ with } V_{neutral} = \frac{V_{bus}}{2}$$

$$V_{phase-phase} = \sqrt{3} \cdot V_{pk} = \frac{\sqrt{3}}{2} \cdot V_{bus}$$

Adding a third harmonic modulation to the previous reference sinewave decreases the overall amplitude of the resulting PWM modulation (PWM duty cycle never reaches either 0% or 100%, Figure 1. right). This is due to the fact that the minimum of the 3rd harmonic corresponds to the maximum of the fundamental and vice versa.

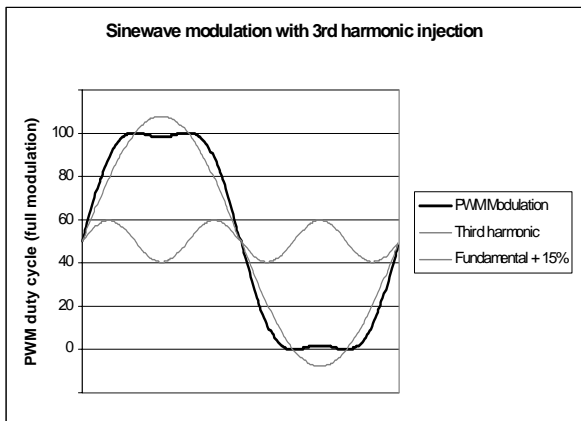
Figure 1. Pure sinewave modulation and equivalent with third harmonic added



As a consequence, this allows the fundamental signal amplitude to be increased up to the point where the modulating signal reaches the DC bus limits (i.e. 100% PWM modulation)

It can be shown that by applying an appropriate coefficient to the third harmonic component, fundamental amplitude can be increased by 15%.

Figure 2. Third harmonic injection with increased fundamental amplitude



Finally, when considering the phase to phase voltage on the motor, third harmonic components are mutually cancelled out (a 120-degree phase-shift on the fundamental corresponds to a 360-degree shift for the third harmonic) and we have on the motor windings:

- Sinusoidal voltage (and therefore currents) on the motor
- Phase to phase voltage 15% higher than with pure sinewave PWM modulation

Consequently, this allows you:

- to decrease diameter of copper windings in the motor for a given power rating.
- to increase the current in the motor for a given frequency, therefore providing more output power.
- to increase maximum reachable speed for a given torque, as long as mechanics (ball-bearings mainly) are suited for very high speed operations.

3.2 IMPLEMENTING THIRD HARMONIC INJECTION

Release 2.1 allows you to select either a sine or a sine with third harmonic as the reference PWM modulation. The choice is done by passing the appropriate parameter to the IMC_SetWaveform function of the IMC software modules:

- PURE_SINE,
- SINE_3HARM.

The corresponding look-up-tables are delivered with the library (in IMCParam.h) and use 256 bytes each. They were calculated using the sine3.xls spreadsheet delivered in the utility directory.

The previous sinewave generation method (in release 2.0) uses the fact that the sum of the three sinewave modulated signals in a balanced three phase system is null. This allowed to reduce CPU load by computing only two out of the three PWM signals, the last one being just a complemented sum of the first two.

This is no longer true for third harmonic injection and the three PWM signals have now to be calculated, thus increasing the CPU load slightly (from 15% to 19%).

4 LIBRARY MIGRATION AND RELATED ISSUES

The V2.1 library release has been migrated following the guidelines provided with the “V4 to V6 migration notes” document which can be found in the ST9+ V6 Toolchain User Documentation folder.

The sections here below detail the main differences compared to the V4 Toolchain. It should be noted that neither code density nor execution speed have been modified due to library migration.

4.1 C FILES

Aside from syntax modifications, not discussed here, the main change to the code is the removal of the `SAVE_PAGE()` and `RESTORE_PAGE()` functions in the interrupt service routines (now automatically added by the compiler in the interrupt prologue/epilogue).

Furthermore, the `ZPC_IT` interrupt is now declared as a standard interrupt routine.

4.2 TR9 AND ASSEMBLY FILES

Not applicable: no assembly files in the library.

4.3 LINKER SCRIPTFILE

A new scriptfile `ST92141.ld` has been created for the library, using the V6 Toolchain new features.

It should be noticed that this scriptfile may be used for any projects running on ST92141: each memory section (EPROM/ROM and RAM) is addressed using a single DPR pointer, which is not changed during code execution (as ROM is 16KB only).

The only part which should be customized is the stack size (currently set to 256 bytes for development purposes); refer to Section 4.4 for stack usage description.

Maximum stack depth measured during library validation was 88 bytes¹⁾.

¹⁾Measured on the HDS2V2 emulator with library release adapted to V6.1 Toolchain, in closed loop mode, corresponding to the deepest level of function calls interrupted by two nested interrupts.

4.4 START-UP FILES

Two modifications were made to the crtbegin.spp file given as examples in the toolchain package:

- interrupt vector declaration.
- MMU set-up: the loadings of DPR1 and DPR2 are commented (these sections are not used and corresponding labels `_idpr1` and `_idpr2` are not defined by the linker).

Using the crtbegin.spp file included in the toolchain package ensures consistency with tools deliveries, but implies two major changes in the mapping of the application:

- There's now only one stack used during code execution: the system stack, mapped in RAM (in V4 release, both stacks are used: the system stack in register file and the user stack in RAM).
- The working register group used by the C compiler is now group D (it was previously group 0 with the V4 Toolchain). Consequently, the register file mapping (done in `reg-file.h` header file) has changed:
 - The library's dedicated registers are now placed between R0 and R37 (included)
 - registers R38 to R207 are free for the user.

One should keep in mind that the execution time may be significantly reduced by extensively using the register file (either for system stack or variables, the user stack must stay in RAM).

4.5 MAKEFILE

Options passed to the C compiler and the linker have been updated according to the new set of options available with the V6 Toolchain:

- `-nostartfiles`: this specifies that start-up files (`crtbegin.spp`,...) have to be searched in the working directory and not in the tools directory
- `-mswitch-in-rodata`, which saves `spm/sdm` sequences in functions when using jump tables.
- `-O3`, corresponding to the maximum level of optimization; this option may be disabled to ease the debugging phase.
- `-Wall`, `-W`, `-Wstrict-prototypes`, `-Wmissing-prototypes`: these options have been enabled to give users an optimum level of warning messages. This level may be nevertheless increased, on a case by case basis, by modifying the C compiler options

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