



ST & Arrow EV Compressor Controller Solution based on *ST SPC560P40*

May 30, 2019



Content

1. Arrow EV Compressor Driver Solution Block Diagram & Features
2. SPC560P40L1 Key Features Used
3. ST Algorithm Libraries Used
4. ST GUI Settings Used
5. Development Issues Sharing
6. Arrow Solution with ST MCU Advantages

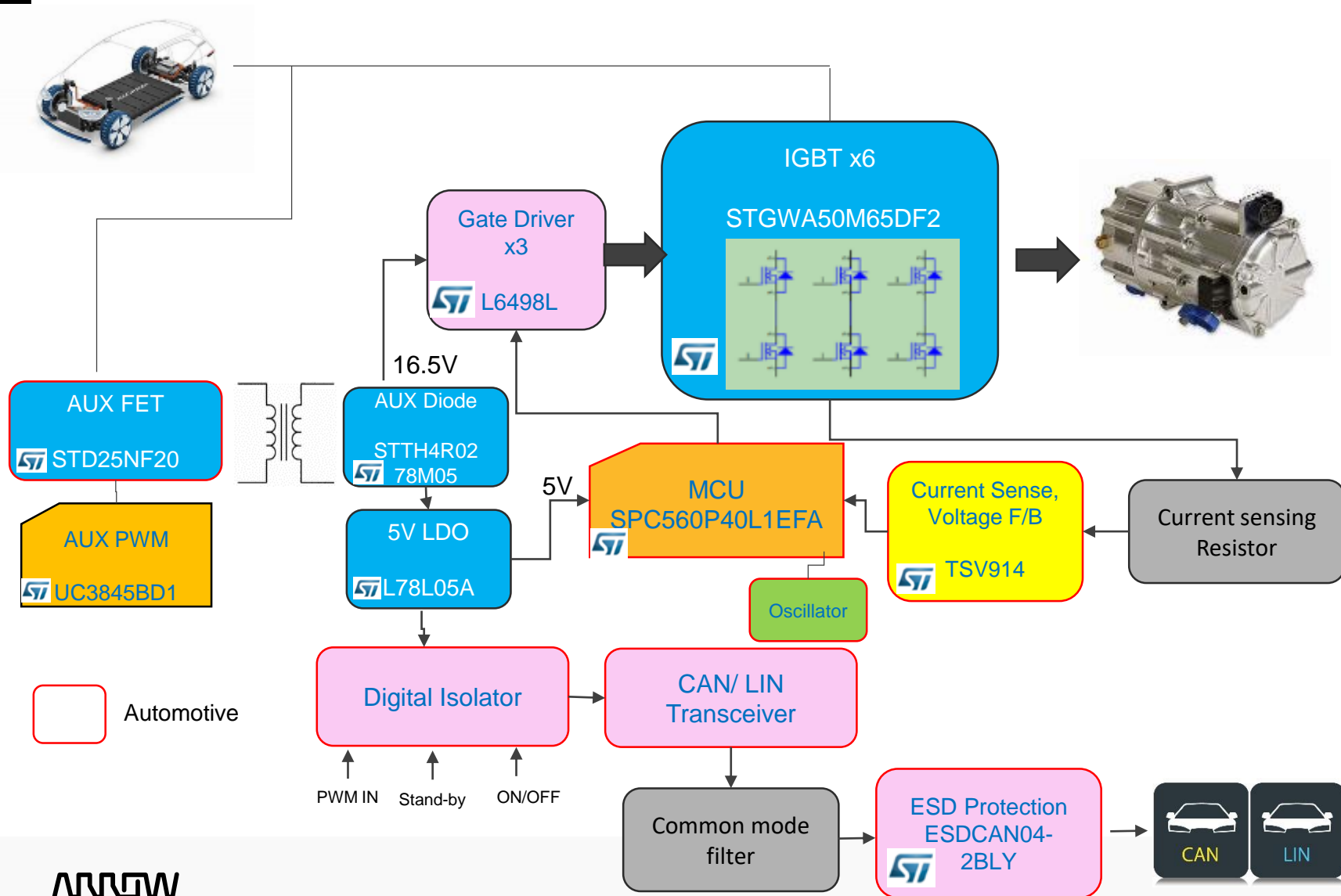
ST & Arrow 3.5kW EV Compressor Controller

> Features:

- > Input Voltage: 320VDC
- > Output Power: Max 3500W
- > 1000-6000 rpm BLDC/PMSM/IPM compressor compatible
- > Efficiency 96%
- > Automotive Grade
- > Sensorless FOC control algorithm
- > Support High Pressure Start-up
- > Low noise
- > OVP, LVP, OCP, OTP
- > CAN/LIN/PWM control

> Applications:

- > In Vehicle Air-conditioning Compressor

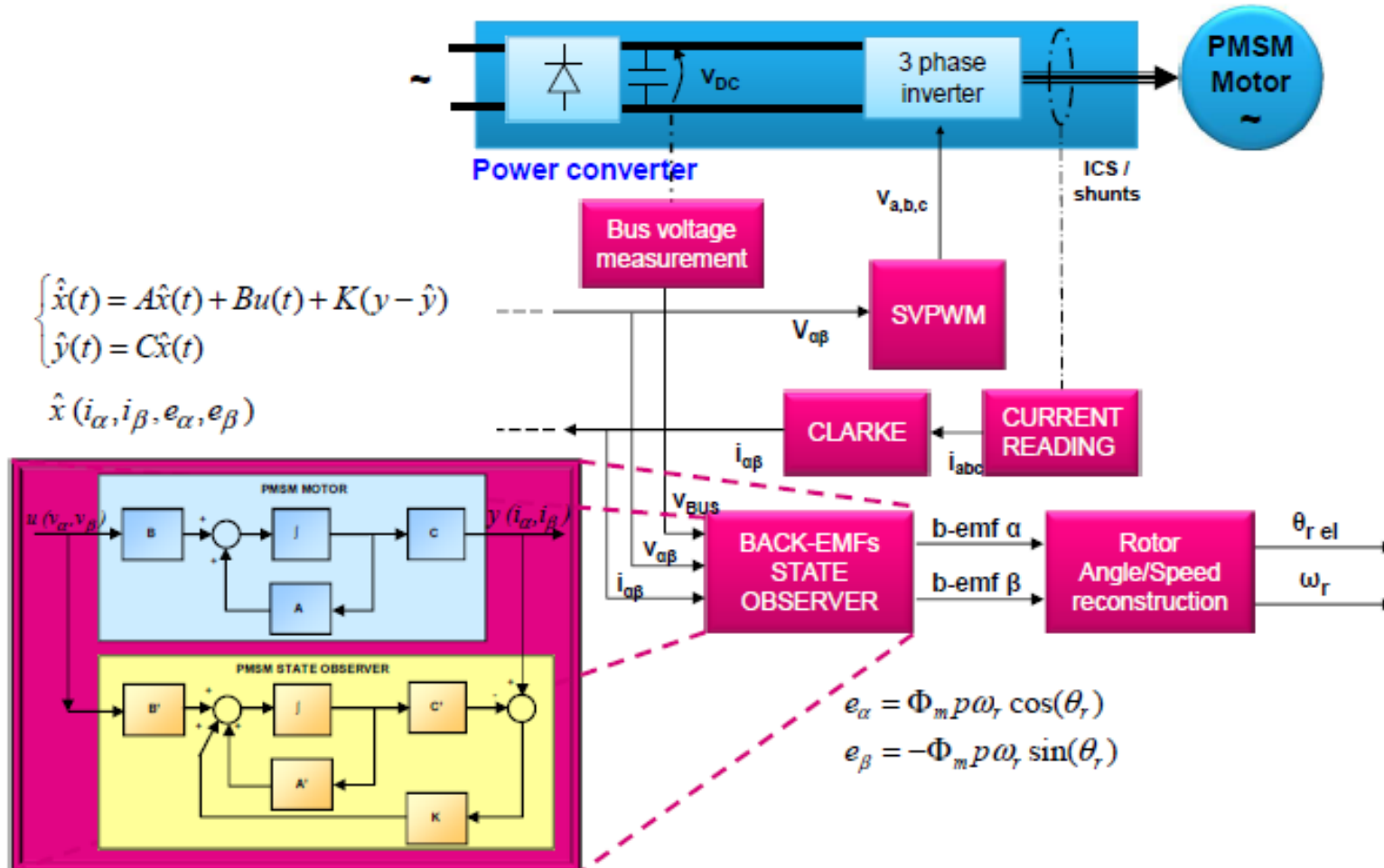


SPC560P40L1 Key Features

Automotive Grade

- Up to 64 MHz, single issue, 32-bit CPU core complex (e200z0h)
 - Compliant with Power Architecture® embedded category
 - Variable Length Encoding (VLE)
- Memory organization
 - Up to 256 KB on-chip code flash memory with ECC and erase/program controller
 - Additional 64 (4 × 16) KB on-chip data flash memory with ECC for EEPROM emulation
 - Up to 20 KB on-chip SRAM with ECC
- Fail-safe protection
 - Programmable watchdog timer
 - Non-maskable interrupt
 - Fault collection unit
- Nexus Class 1 interface
- Interrupts and events
 - 16-channel eDMA controller
 - 16 priority level controller
 - Up to 25 external interrupts
 - PIT implements four 32-bit timers
 - 120 interrupts are routed via INTC
- 1 FlexPWM unit: 8 complementary or independent outputs with ADC synchronization signals
- Fault pin input for current protection
- 1 general purpose eTimer unit
 - 6 timers each with up/down capabilities
 - 16-bit resolution, cascadable counters
 - Quadrature decode with rotation direction flag
 - Double buffer input capture and output compare
- GPIO (37 on LQFP64; 64 on LQFP100) individually programmable as I/O or special function
- Communications interfaces
 - 2 LINFlex channels (1× Master/Slave, 1× Master only)
 - Up to 3 DSPI channels with automatic chip select generation (up to 8/4/4 chip selects)
 - Up to 2 FlexCAN interface (2.0B Active) with 32 message buffers
 - 1 safety port based on FlexCAN with 32 message buffers and up to 8 Mbit/s at 64 MHz capability usable as second CAN when not used as safety port
- One 10-bit analog-to-digital converter (ADC)
 - Up to 16 input channels (16 on LQFP100 / 12 on LQFP64)
 - Conversion time < 1 μs including sampling time at full precision
 - Programmable Cross Triggering Unit (CTU)
 - 4 analog watchdogs with interrupt capability, analog watchdogs comparing ADC results against predefined values (low, high range) before results are stored in ADC Result location
- On-chip CAN/UART bootstrap loader with Boot Assist Module (BAM)

Motor Control Library for 32-bit Power Architecture® MCU's Available



• Functions

- Single PMSM FOC sensorless
- B-EMF State Observer, PLL rotor speed/angle computation from B-EMF
- Two shunts (selectable on the Legs or on the Phases)
- Torque control mode
- Speed control mode
- PID regulators
- Flux weakening algorithm.
- Harmonic compensation

Motor Control Library for 32-bit Power Architecture® MCU's- Motor Settings

SPC56xx Motor Control Component



Motor Settings

Power Stage

Drive Management

Control Stage

Magnetic structure Internal PMSM

Electrical parameters

This panel contains electrical and mechanical motor rated parameters.

Pole pairs	<input type="text" value="3"/>	3
Max rated speed	<input type="text" value="8000.0"/>	8000.0 rpm
Nominal Current	<input type="text" value="30.0"/>	30.0 A
Nominal DC Voltage	<input type="text" value="320.0"/>	320.0 V
Rs	<input type="text" value="0.55"/>	0.55 ohm
Ld	<input type="text" value="3.0"/>	3.0 mH
Lq	<input type="text" value="4.5"/>	4.5 mH
Ls	<input type="text" value="0.135"/>	0.135 mH
Autosettings	<input type="text" value="ENABLE"/>	ENABLE
Demagnetizing Current	<input type="text" value="30.0"/>	30.0 A
Back EmfConstant	<input type="text" value="36.96"/>	36.96 Vrms_div_Krpm

Motor Control Library for 32-bit Power Architecture® MCU's- Power Stage

SPC56xx Motor Control Component

Motor Settings

Power Stage

Drive Management

Control Stage

Current Sensing

This panel allows to choose one of the following topologies for reading Current and to set its related parameters

Current Reading Topology

ICS or Two Shunt Settings

Shunt Positioning Phase Sensing selection

Shunt Resistor ohm

Amplification selection Amplification Network Gain

Overall Amplification Gain

Rise Timing ns

Noise Timing ns

Max Readable Current A

Motor Control Library for 32-bit Power Architecture® MCU's- Drive Management

SPC56xx Motor Control Component

Motor Settings

Power Stage

Drive Management

Control Stage

Speed regulator

Execution rate	0.5 ms
KP	1000
KI	512
KP div	64
KI div	16384

Default settings

Control mode	speed control
Target speed	1600.0 rpm
Target stator current flux component	0.0 A
Target stator current torque component	0.0 A

Torque and flux regulators

Execution rate	1 Pwm periods
Cut off frequency	800.0 rad_div_s

Torque

KP	2534
KI	2365

Flux

KP	2534
KI	2365

Startup procedure: advanced

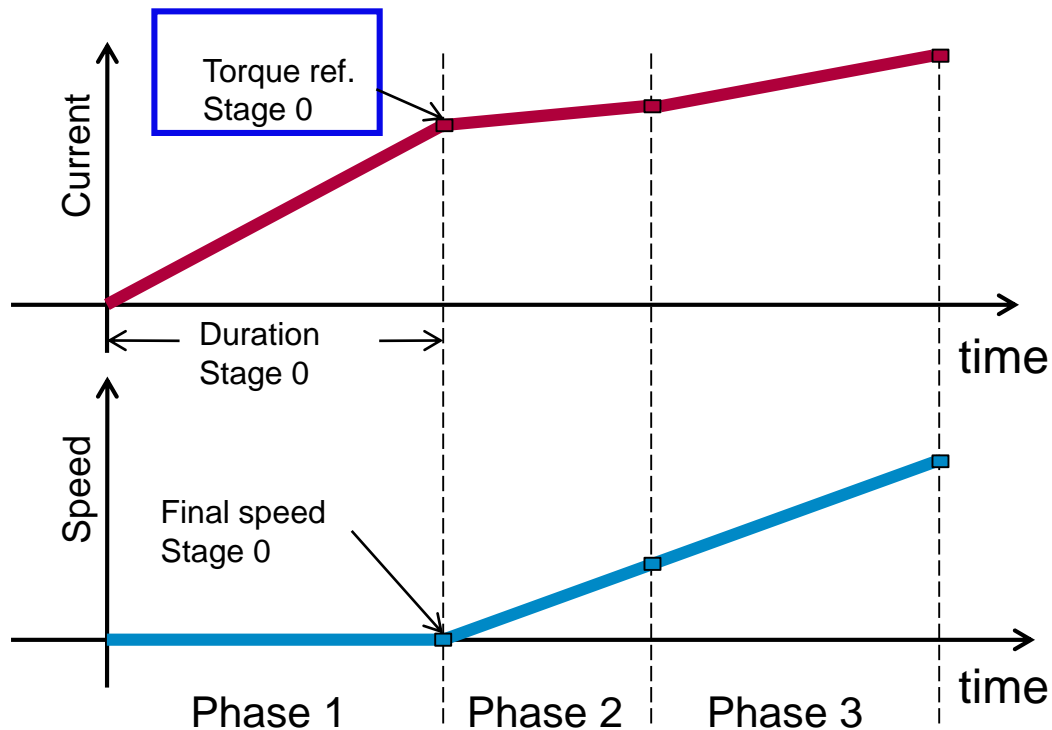
SPC56xx Motor Control Component

Motor Settings

Power Stage

Drive Management

Control Stage



Enable advanced profile

Advanced customized

Alignment electrical angle

Phase 1

Duration

Final speed

Final Current

Phase 2

Duration

Final speed

Final Current

Phase 3

Duration

Final speed

Final Current

Phase 4

Duration

Motor Control Library for 32-bit Power Architecture® MCU's- Control Stage

SPC56xx Motor Control Component

Motor Settings

Power Stage

Drive Management

Control Stage

Inverter driving signal selection

PWM Module	FLEXPWM_Module_0
Low Resource Configuration	<input checked="" type="checkbox"/>
Max PWM modulation	98_PER_CENT
Emergency Fault PIN selection	FAULT_PIN0
Emergency Fault Input Level	FAULT_LEVEL_HIGH

MCU Supply Voltage and Clock Frequency

MCU Supply Voltage	5.0	V
CPU Clock Frequency	64.0	MHz
Motor Control Clock Frequency	64.0	MHz

Additional Features

Additional methods

Flux Weakening Enable

Flux Weakening

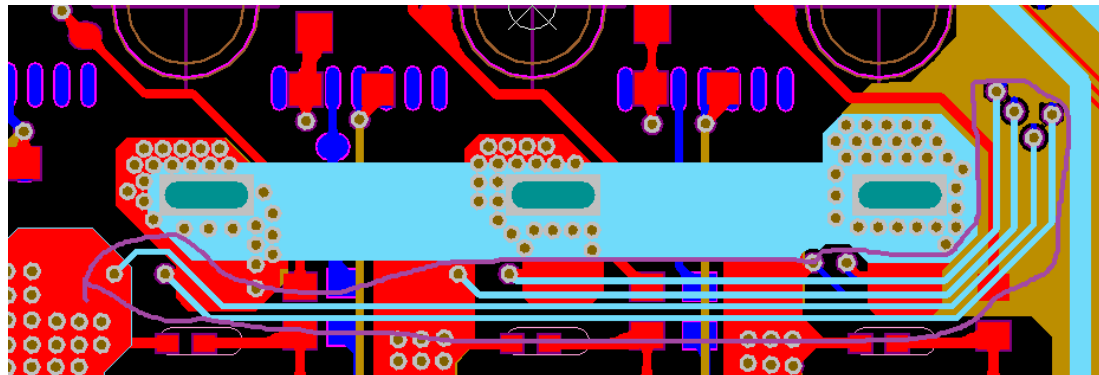
KP	3000	KP div	32768
KI	5000	KI div	32768
Voltage limit	94.0		%

MTPA Enable

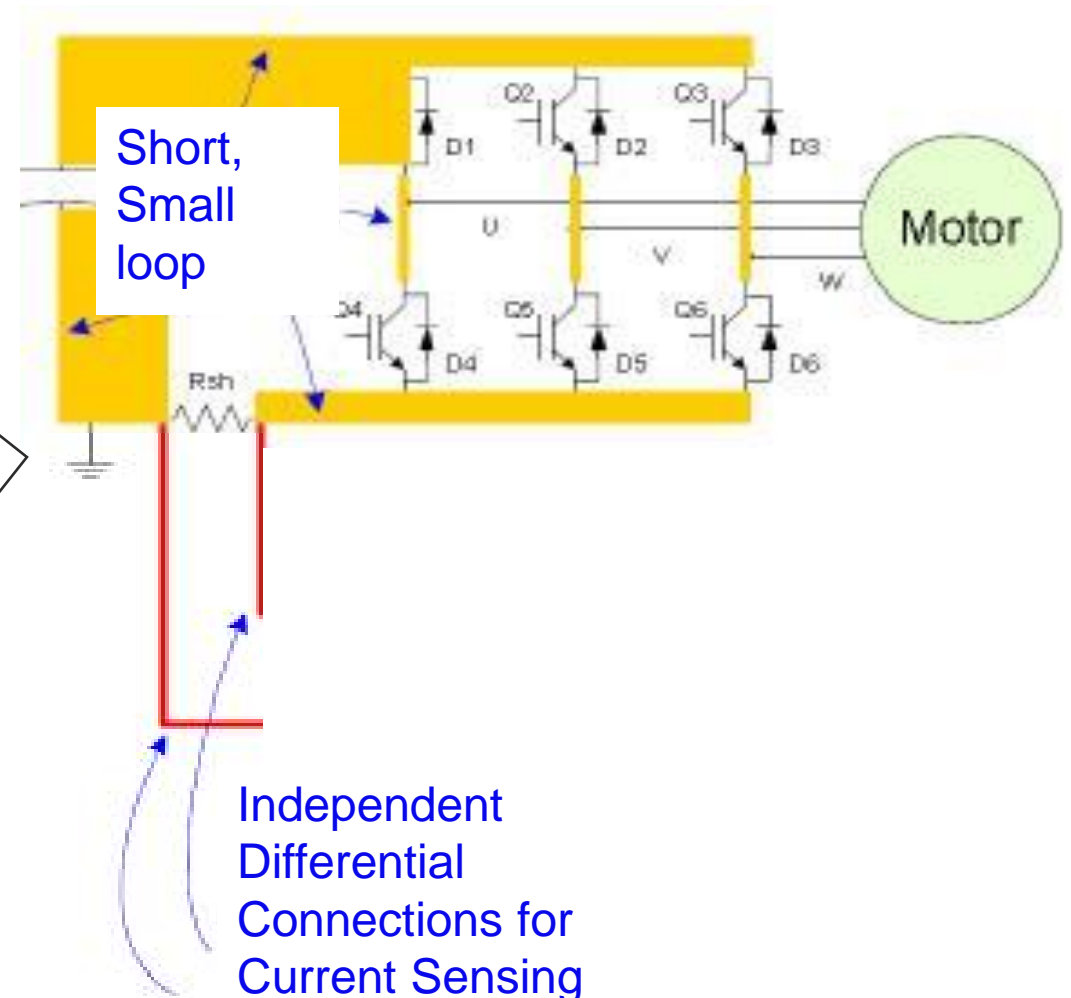
Feed Forward Enable

Development Issue 1 – Layout Noise

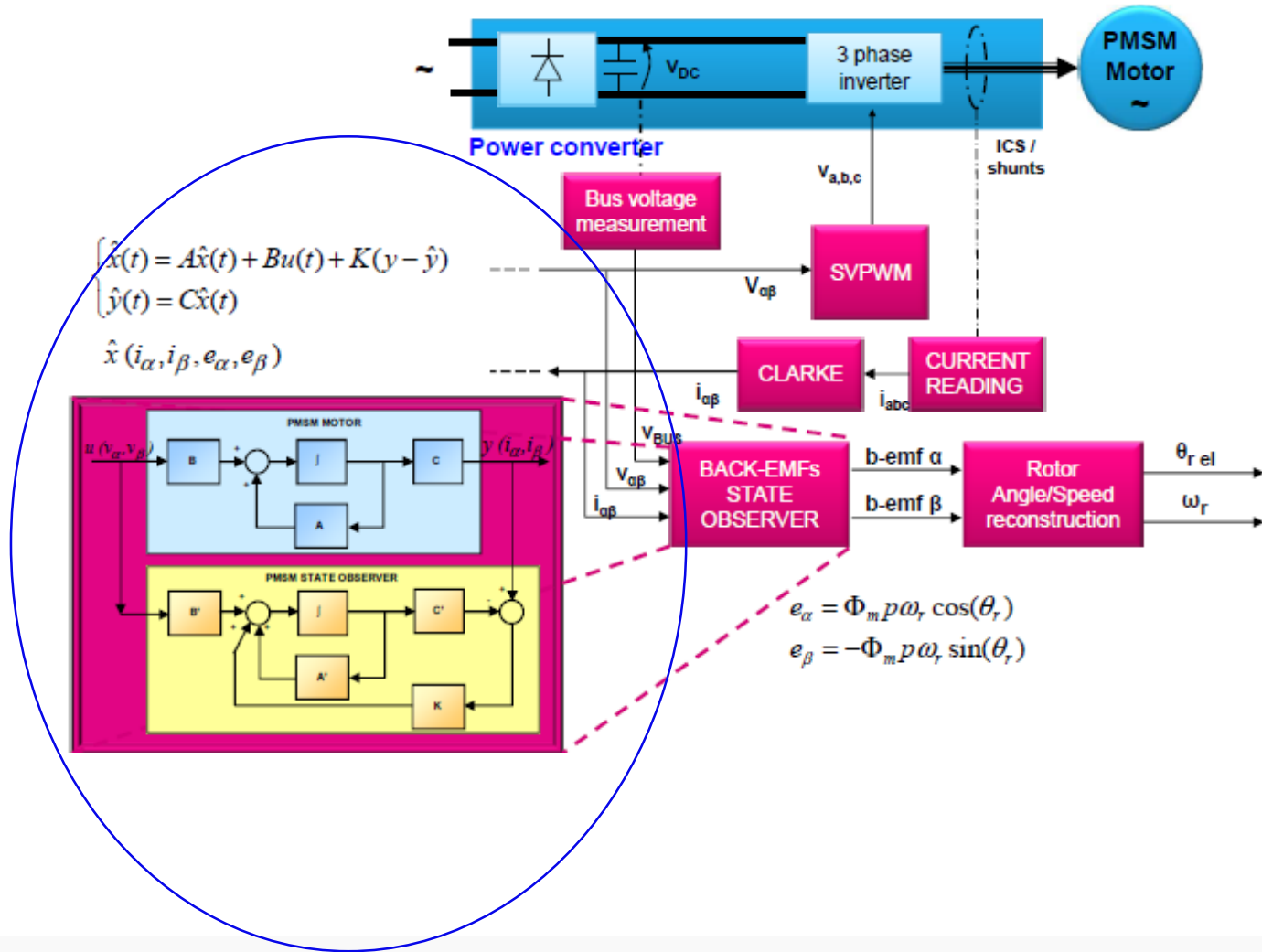
- > Sensorless FOC control algorithm relies solely on the **current signal sampling**
- > To Avoid any Control issues, Need
 - > **Clean** Auxiliary Power Supply DC Output
 - > **Short, small loop** of Main power lines
 - > **Independent, short** Differential Connections for current sensing,
 - > no sharing of the signal ground,
 - > no pass over Vias,
 - > avoid passing through high power circuits



浅蓝色走线是双电阻差分走线

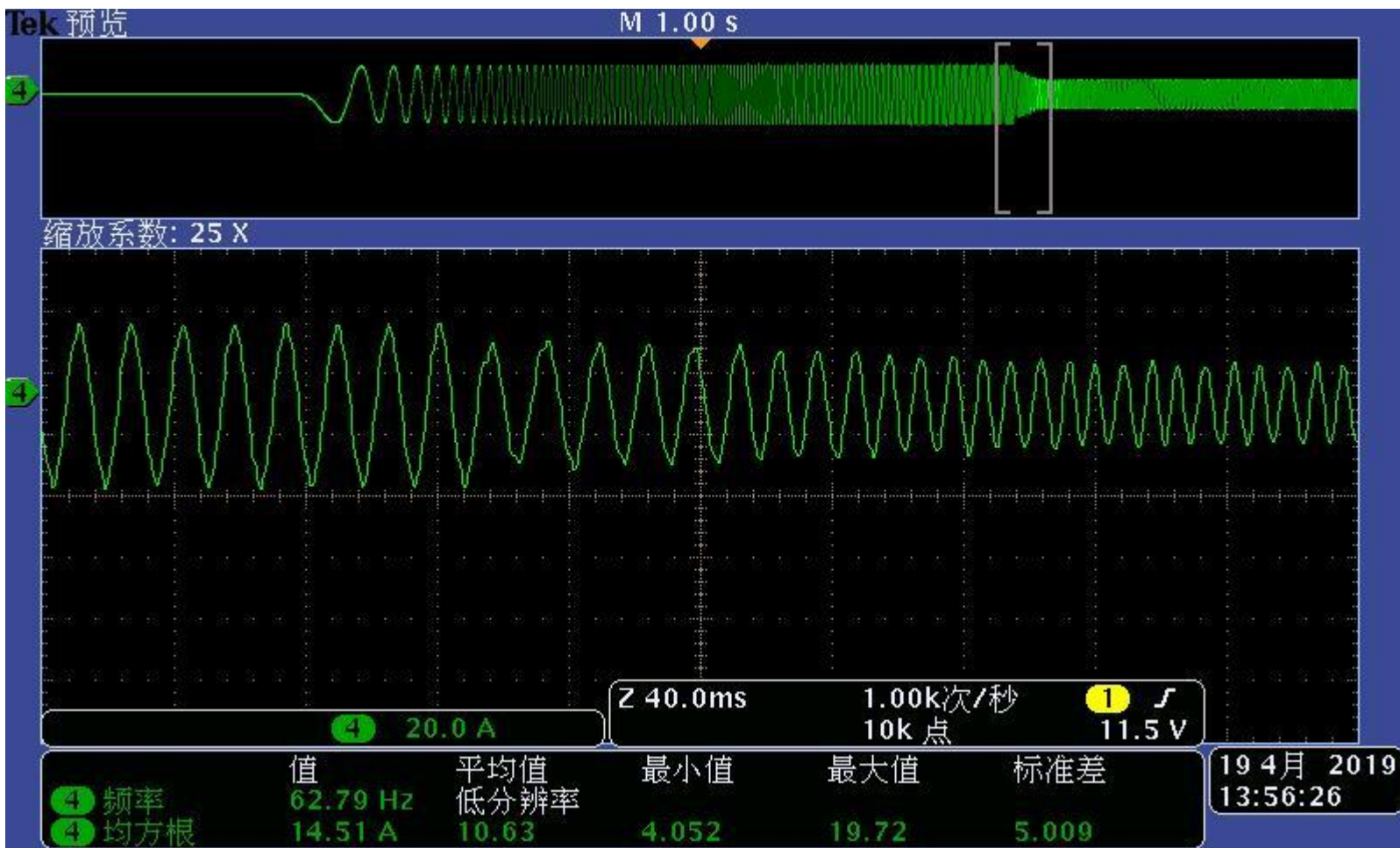


Development Issue 2 – Control Loop Stability



- > For Sensorless control, rotor position needs to be observed from the current signal only, even tiny PCB version spin would lead to difference in software parameters tuning.
- > To increase tuning efficiency, need **User-Friendly Driver Management GUI**, such that results of feedback loop can be seen immediately after multiple settings of :
 - > Current loop bandwidth (KP, KI) 高电流环带宽，电流跟踪快，低电流环带宽，跟踪慢。动态高带宽，稳态低带宽
 - > Speed loop bandwidth (KP, KI) 根据负载匹配速度环
 - > Observer Gain (G1 G2) 高观测器增益收敛速度变快，但是太高容易错误
 - > PLL bandwidth (KP, KI) 跟模型相关，一般不需要调整

Development Issue 3 – Heavy Load startup



- > To avoid Heavy Load start up as False, need MCU with Libraries for
 - > Matching acceleration curves
 - > Matching High & Low Bandwidths
- > ST's MCU libraries have features for
 - > Strong Observer State tracking, **rapid convergence at low speed start-up**
 - > **Quick feedback loop response** at High bandwidth

Motor Phase Current during Start-up at 22kg Pressure Difference

Arrow Solution with ST MCU Advantages

Automotive Grade (Robust ST MCU)

High efficiency (up to 96%)

Shorter development time to market (from Reference Design to Prototype, less than 2 months)

User-friendly (MCU GUI & Development tools)

Strong technical support (from ST & Arrow engineers)

For further information, please contact us:

Arrow China – sales.china@arrowasia.com

Eric Choi (China) – eric.choi@arrowasia.com