Win with InstaSPIN™

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Univ.-Prof. Dr. ir. D.W.J. Pulle RWTH-ISEA Germany
CEO EMsynergy, Australia

Member Texas Instruments InstaSPIN Development Team

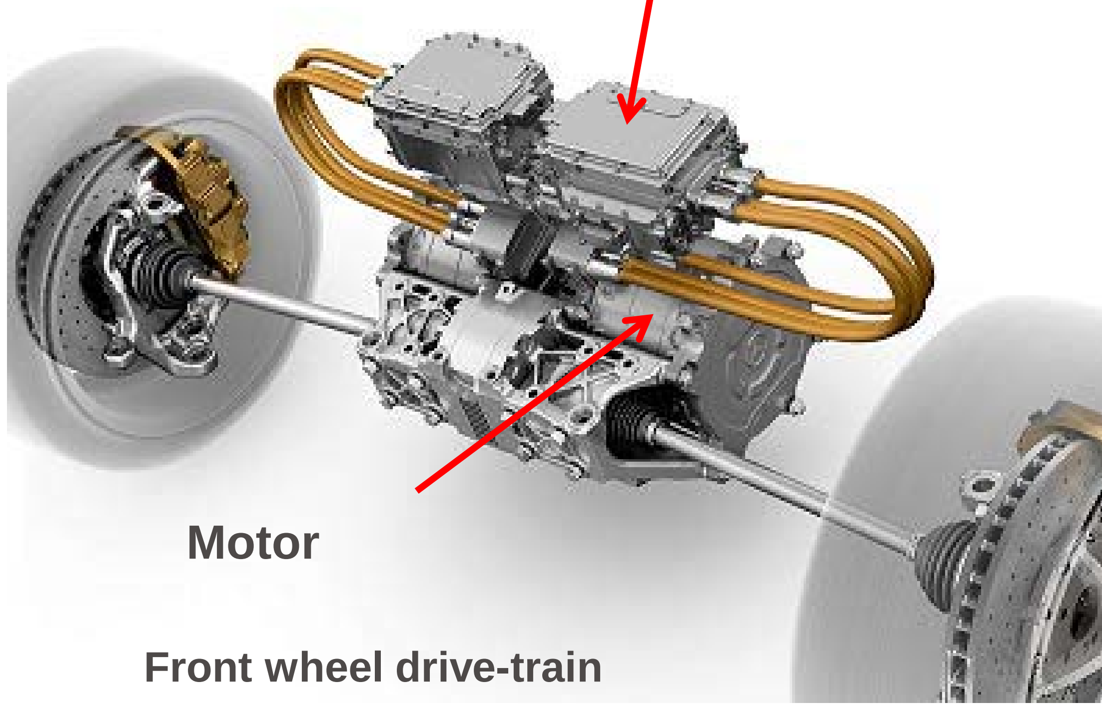
Content

- Introduction
  - what is sensorless control?
- Challenges to realise sensorless control
  - Ability to track the magnetic field in the machine
  - Need to identify and track critical motor parameters
  - Measurement of the induced voltage
- Solutions
  - use of TI InstaSPIN algorithm
  - Use of VisSim embedded control tools
  - PLECS processor in the loop (PIL) technology
- Application examples
- Questions ?

Introduction: typical electrical drive

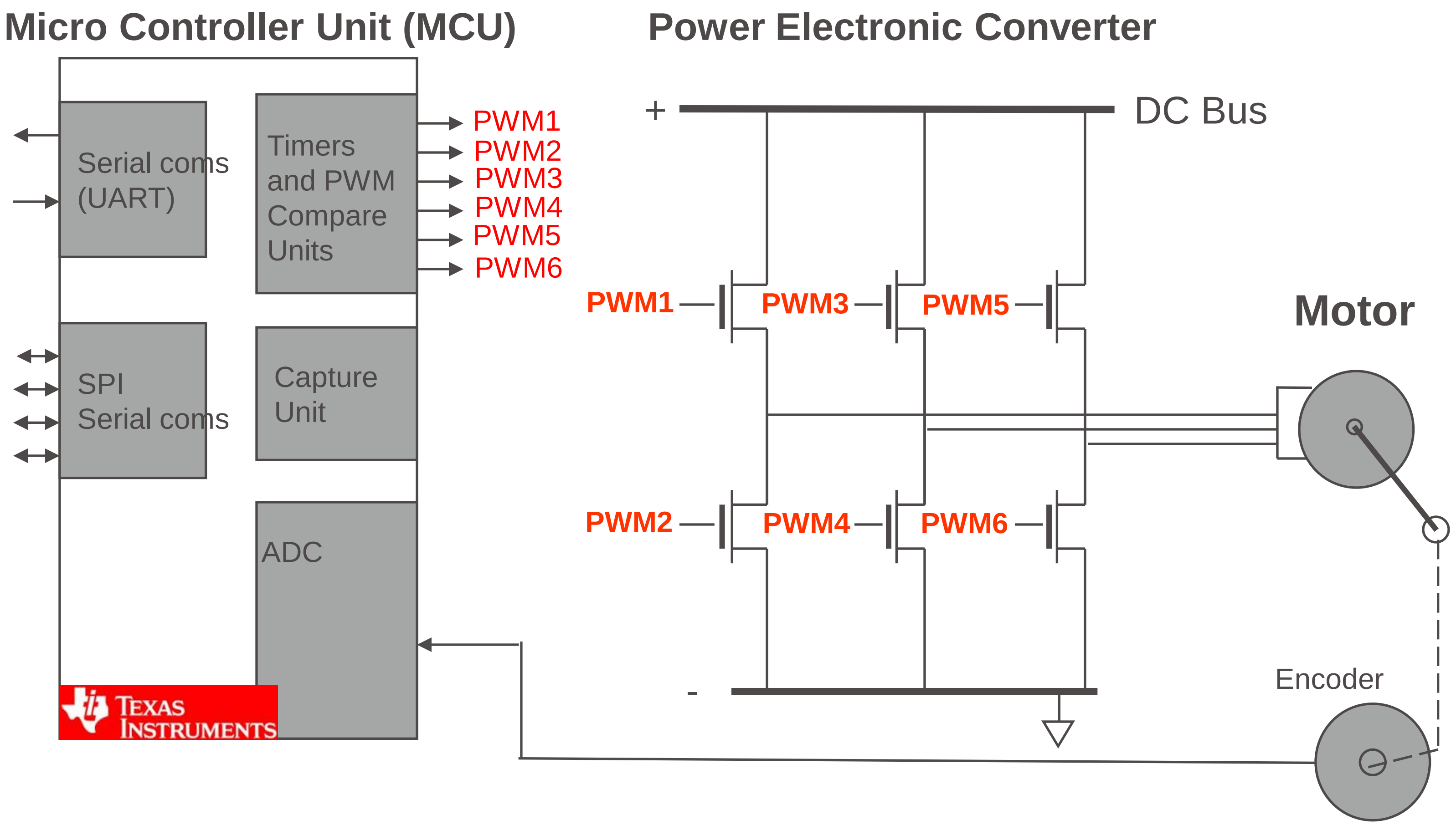
Power Electronic Converter with controller and micro-processing unit (MCU)

Mercedes SLS
Electric vehicle



➔ Schematic representation electrical drive ?

Introduction: typical electrical drive



➔ What is 'Field Oriented Control' (FOC) ?

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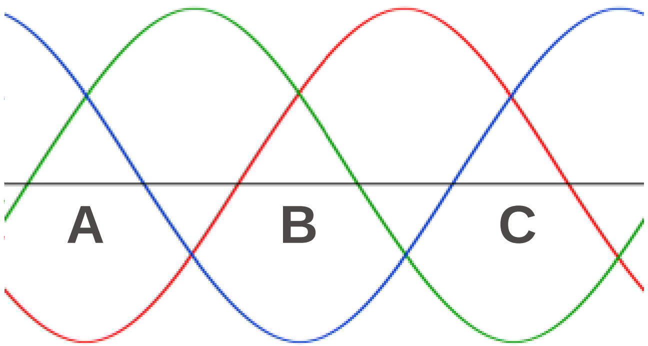
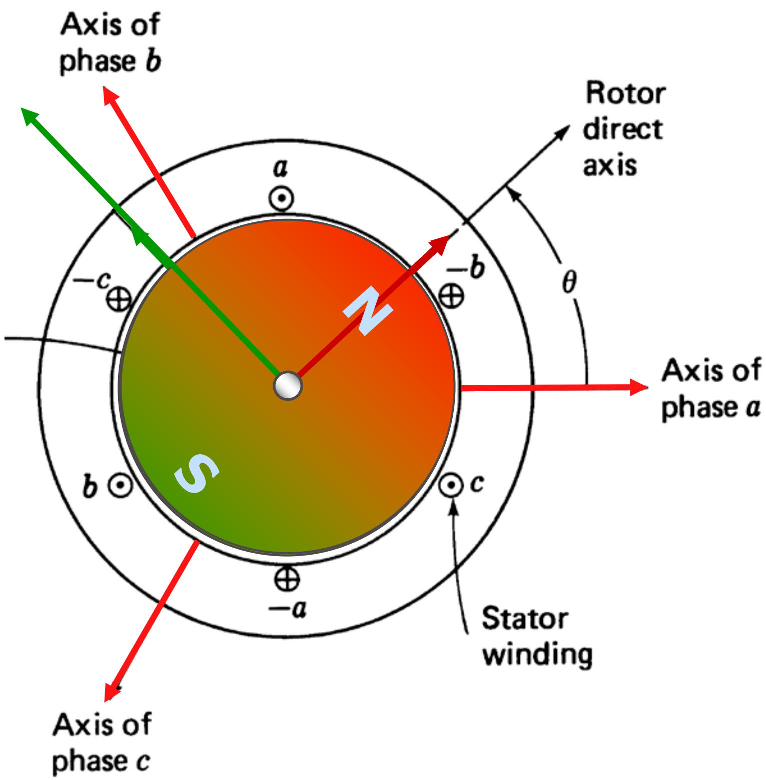
Low Torque

Medium Torque

High Torque

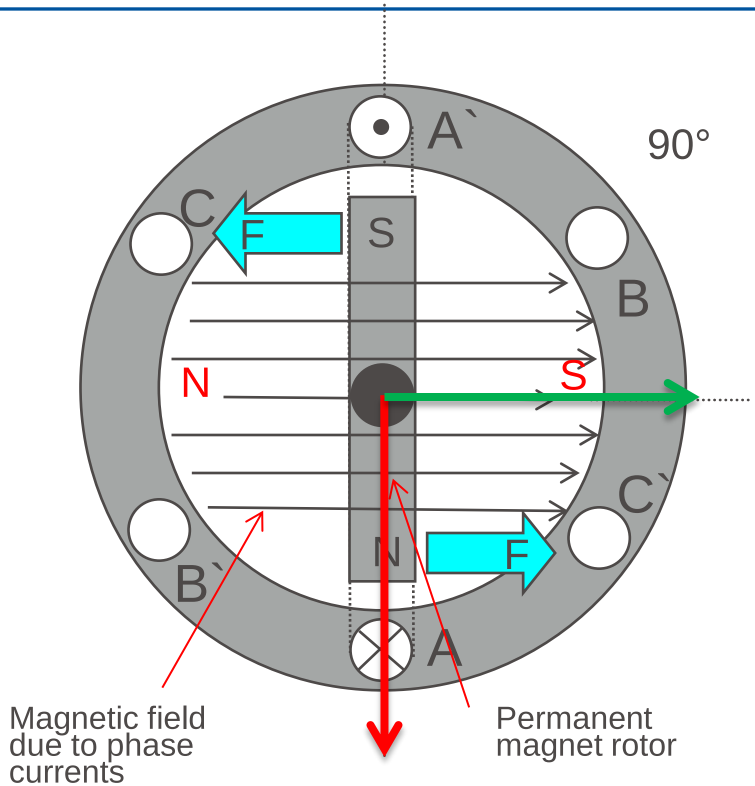


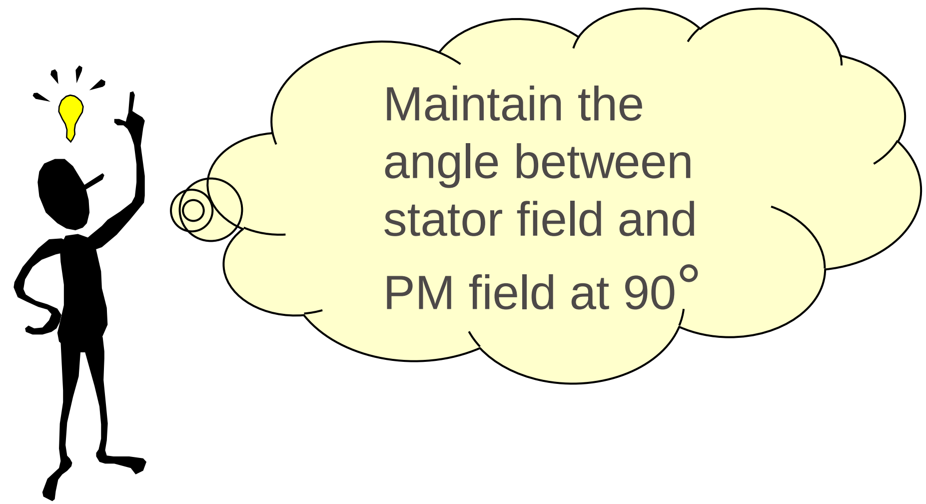


$$Torque \propto \psi_{PM} I_q$$

Adjustable

Introduction: What is 'Field Oriented control' ?





Principle of 'Field Oriented Control' (FOC) for PM [1], [2]

- Gives highest torque for the lowest current
- High dynamic response fully equivalent to DC motor
- Requires control of the currents in the stator by using the converter
- Requires knowledge of the PM magnetic field orientation

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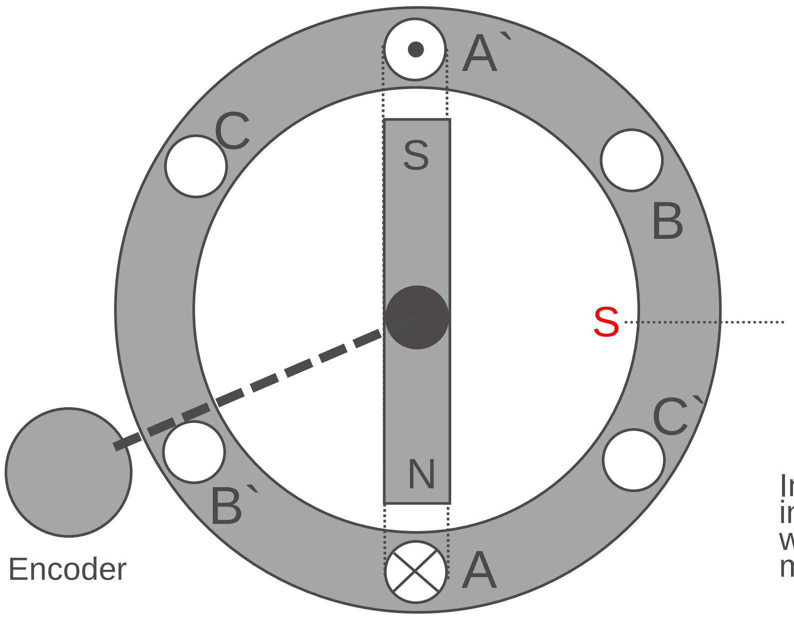
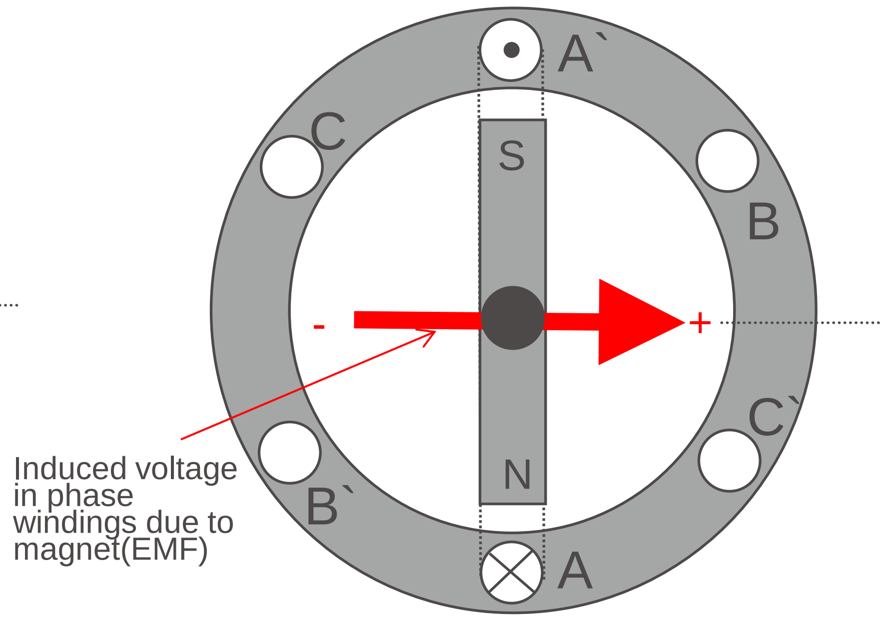


Use of a shaft encoder

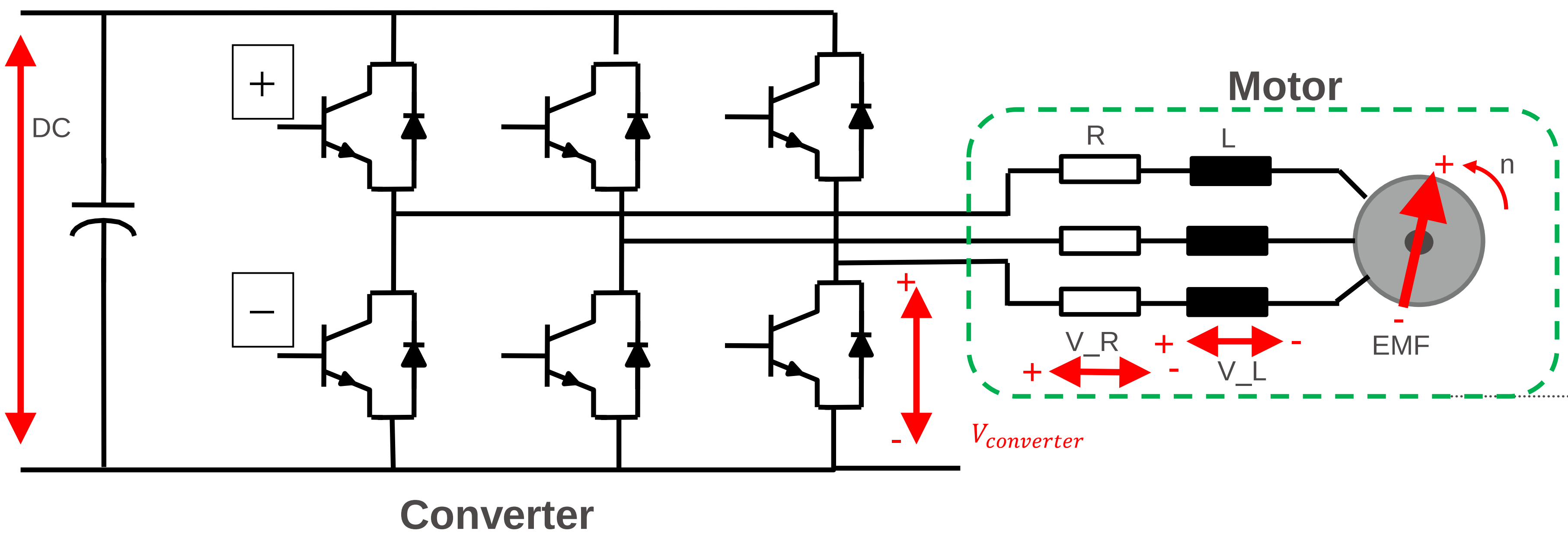


Use EMF induced by rotor magnets

- Shaft encoder: reliable position information, but expensive , increases drive complexity and requires an additional cable to MCU
- Encoder: requires access to a motor shaft end and increases motor volume
- EMF sensing required sohisticated algorithm that works at near zero speed

Challenges to achieving sensorless control

- Need to find EMF 'vector' in amplitude and orientation using
  - $EMF = V_{motor} - V_R - V_L$
  - Approach requires knowledge of the motor parameters R, L and currents



➔ Complication: motor voltage (V_{motor}) must be reconstructed from converter voltage ($V_{converter}$) which has a value V_DC or 0 V

Challenges to achieving sensorless control

- Estimate the rotor flux in terms of amplitude AND orientation
  - Undertake this at near zero speed and remain STABLE at zero speed
  - Estimate the motor parameters in order to 'reconstruct the EMF of the motor
  - Be used universally for all three-phase machines (PM and INDUCTION)
  - Accurate measurement of the motor voltages and currents

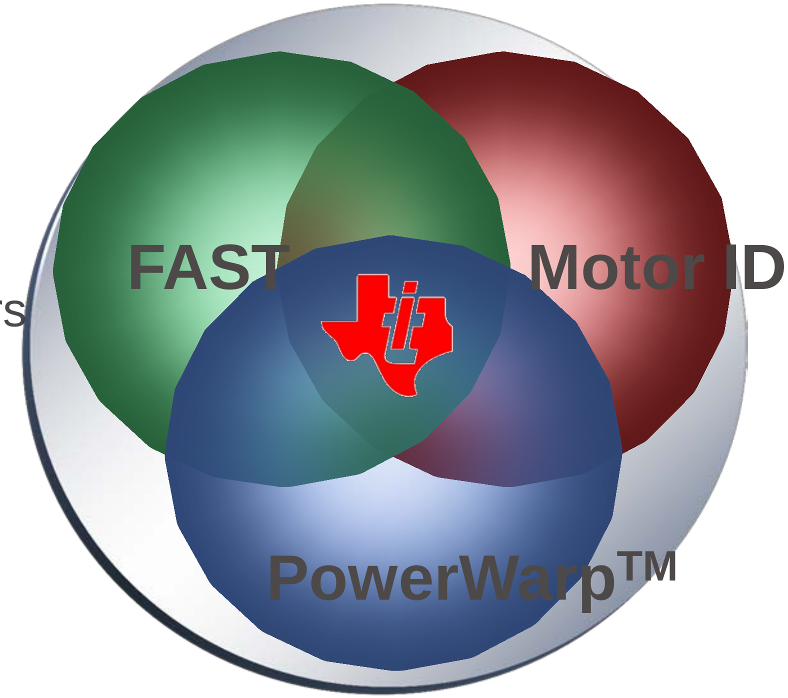
- Need for a software package than can communicate with the sensorless algorithm at a 'high level' so

  that inexperienced users can use this technology: VisSim
- Need for a software package that can evaluate sensorless operation with a model of the machine and converter: PLECS PIL

➔ Solution??

Solution to realizing sensorless control

- Use of Texas Instruments InstaSPIN™-FOC [3]
  - A new advanced field oriented control technique for sensorless control of permanent magnet (salient and non-salient) and Induction motors
  - Comprehensive self- commissioning capabilities
  - On-line estimation of key variables
  - Relatively easy to use by inexperienced users
- What are the components ?
  - FAST algorithm that provides:
    - Flux amplitude , Angle and Speed of the flux vector and machine Torque
  - Motor ID:
    - Identification of motor parameters
  - PowerWarp:
    - Energy efficient induction machine operation under partial load



➔ System architecture using InstaSPIN-FOC?

Solution to realizing sensorless control

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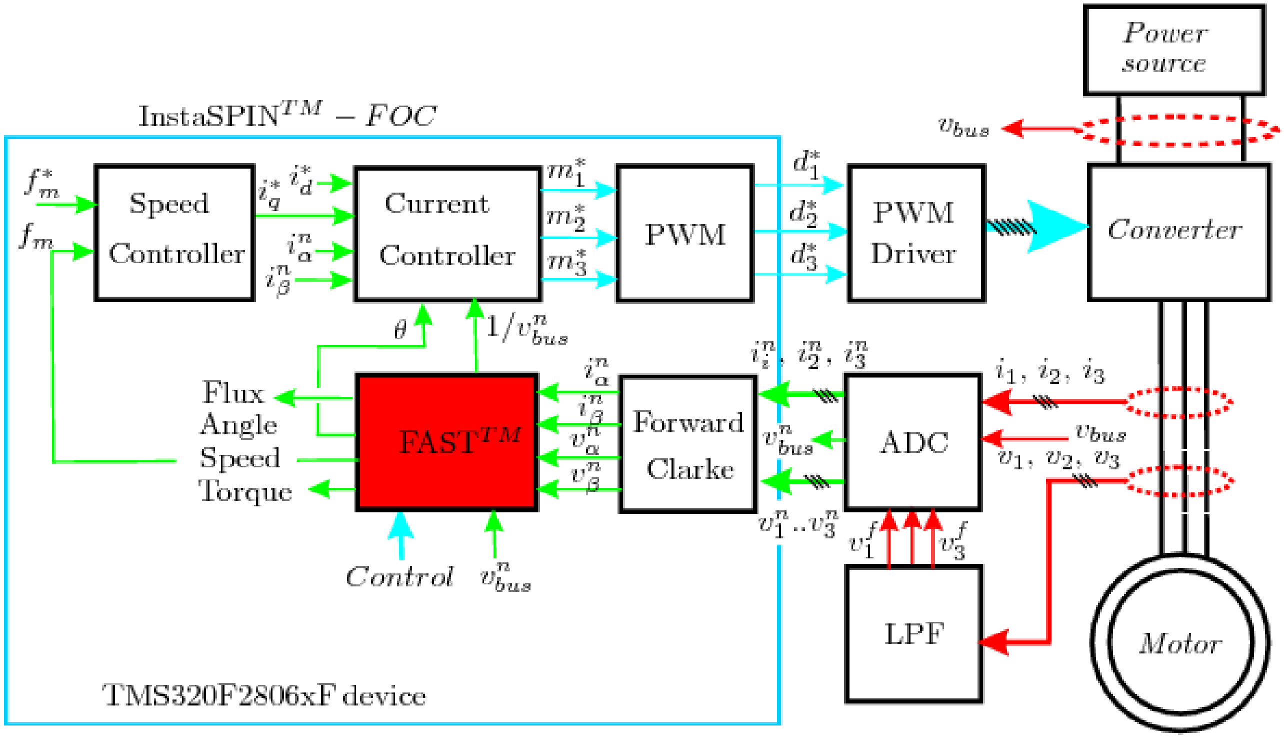
- System architecture of InstaSPIN-FOC located in MCU: TMS320F280xF

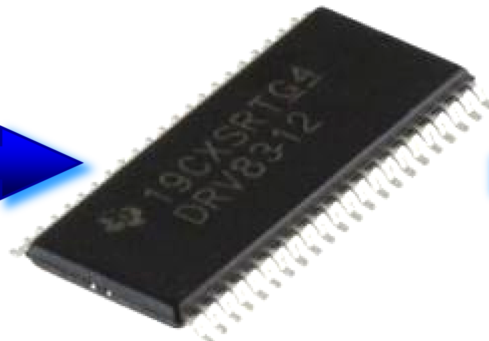


- FAST module: provides flux amplitude/angle/speed and torque
- required speed and current control algorithms to achieve FOC

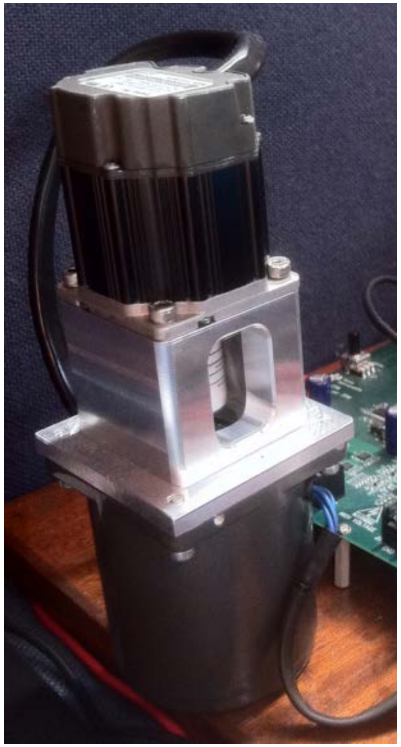
➔ Tool set ?

Solution to realizing sensorless control

027F-069M MCU



DRV8312 Kits
DRV8301 Kits



High Voltage Motor Control + PFC Kit

C2000 Launchpad (027 and 069) and Booster Pack

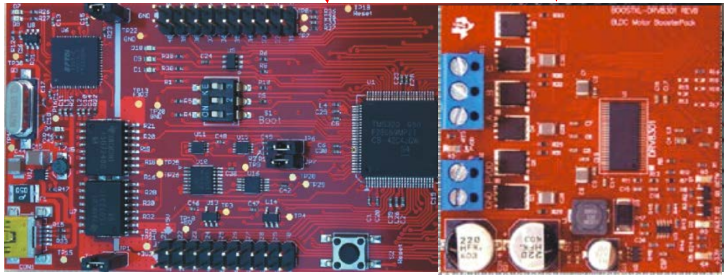
TI PM/IM Motors

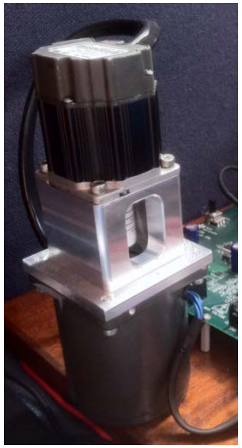
InstaSPIN-FOC

- BLDC FOC
- ACIM FOC (3 and 1 phase)
- PMSM FOC
- IPM FOC
- Stepper FOC (Pending release)

Solution to realizing sensorless control

- Development solutions:
- System components:
  - DRV 8312-069M -kit (24V/3.5A)
  - DRV 8301-069M -kit (60V/40A)
  - HV+PFC kit (350V/10A)
  - LaunchPad (027 and 069M) with Booster pack (24V/10A)





➔ What development tools are available to apply InstaSPIN??

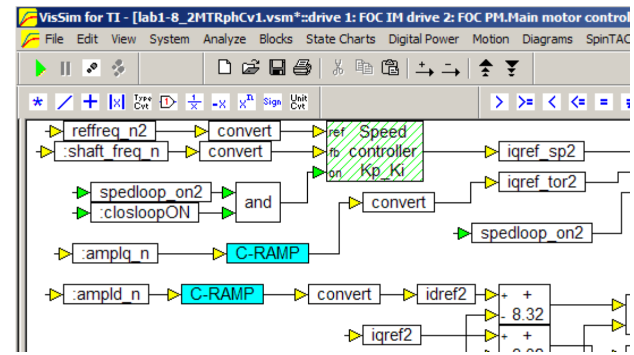
InstaSPIN™ development tools

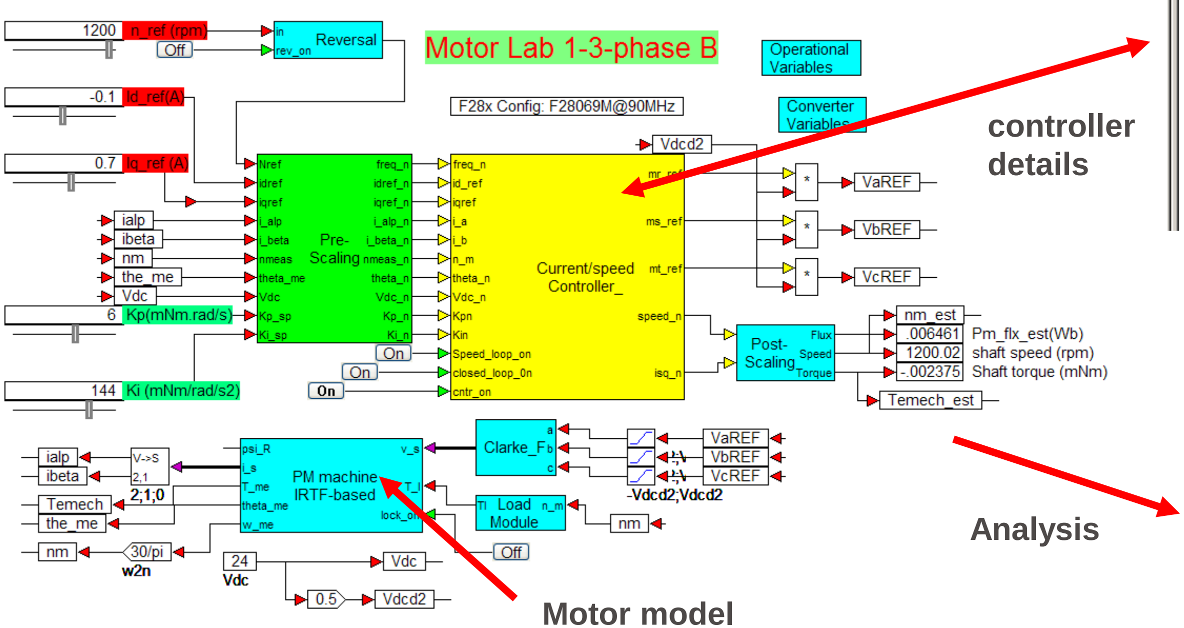
- VisSim™
  - Embedded control software
  - Use of custom designed InstaSPIN™ modules
- MotorWare™
  - Texas Instrument development tools
  - Includes set of MotorWare™ laboratories which use InstaSPIN™
- PLECS ™
  - Software simulation environment with electrical and control block set
  - PLECS processor in the loop (PIL) technology, works together with (PIL prepared) MotorWare™ laboratories that use InstaSPIN™

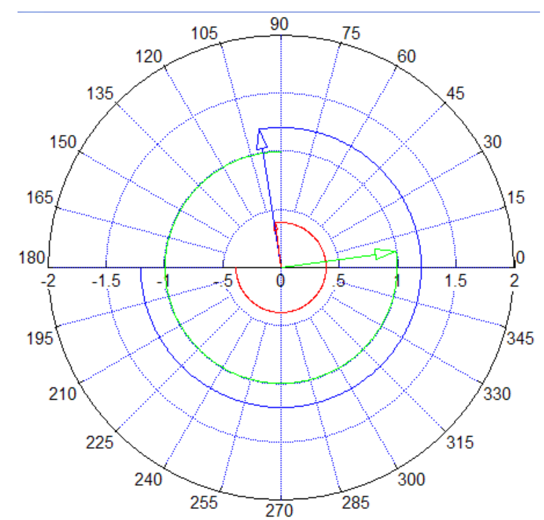
➔ Closer look at development tools

InstaSPIN™ development tools

- Example of VisSim [4] 'embedded control' development software
  - Ability to develop and veritfy a fixed point control algorithm for the MCU and test this with a simulated motor model first



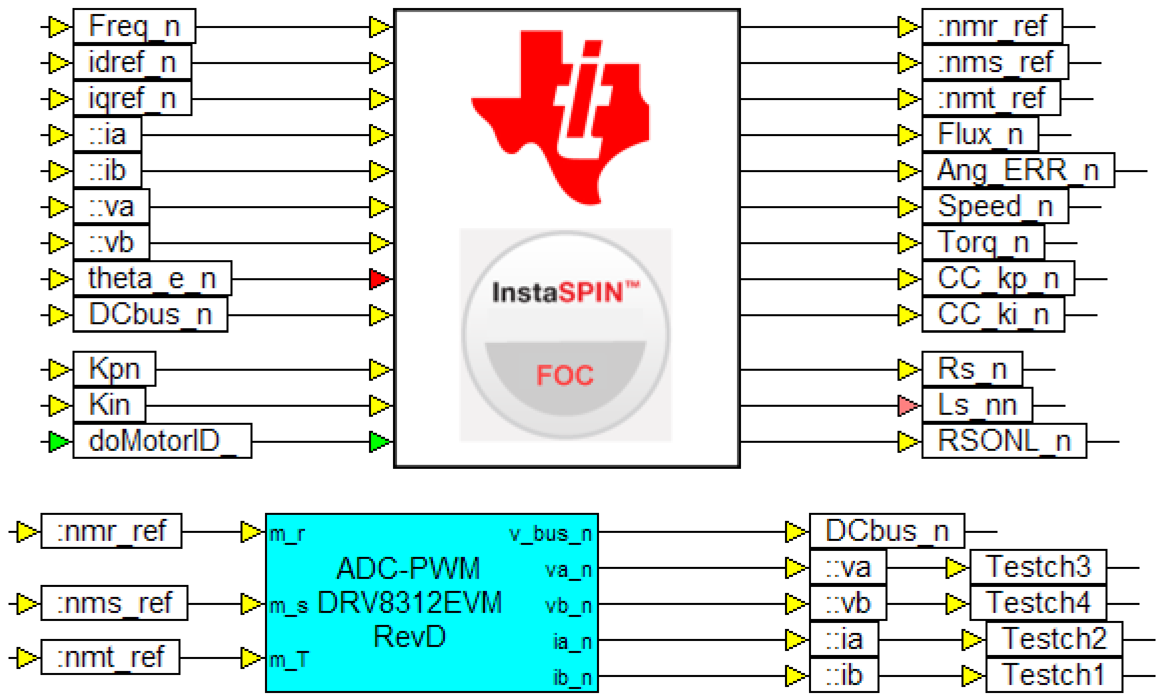




➔ VisSim for sensorless control using InstaSPIN?

InstaSPIN™ development tools

- Use of VisSim to develop complete sensorless embedded controller structure
- Modules present:
  - InstaSPIN-FOC : specially designed VisSim module [5] which executes the FAST algorithm and all control tasks
  - ADC-PWM: module used to obtain the measured voltage/currents and controls the power electronic converter



➔ Compilation of this module to C-code generates an 'outfile' that runs the drive

InstaSPIN™ development tools

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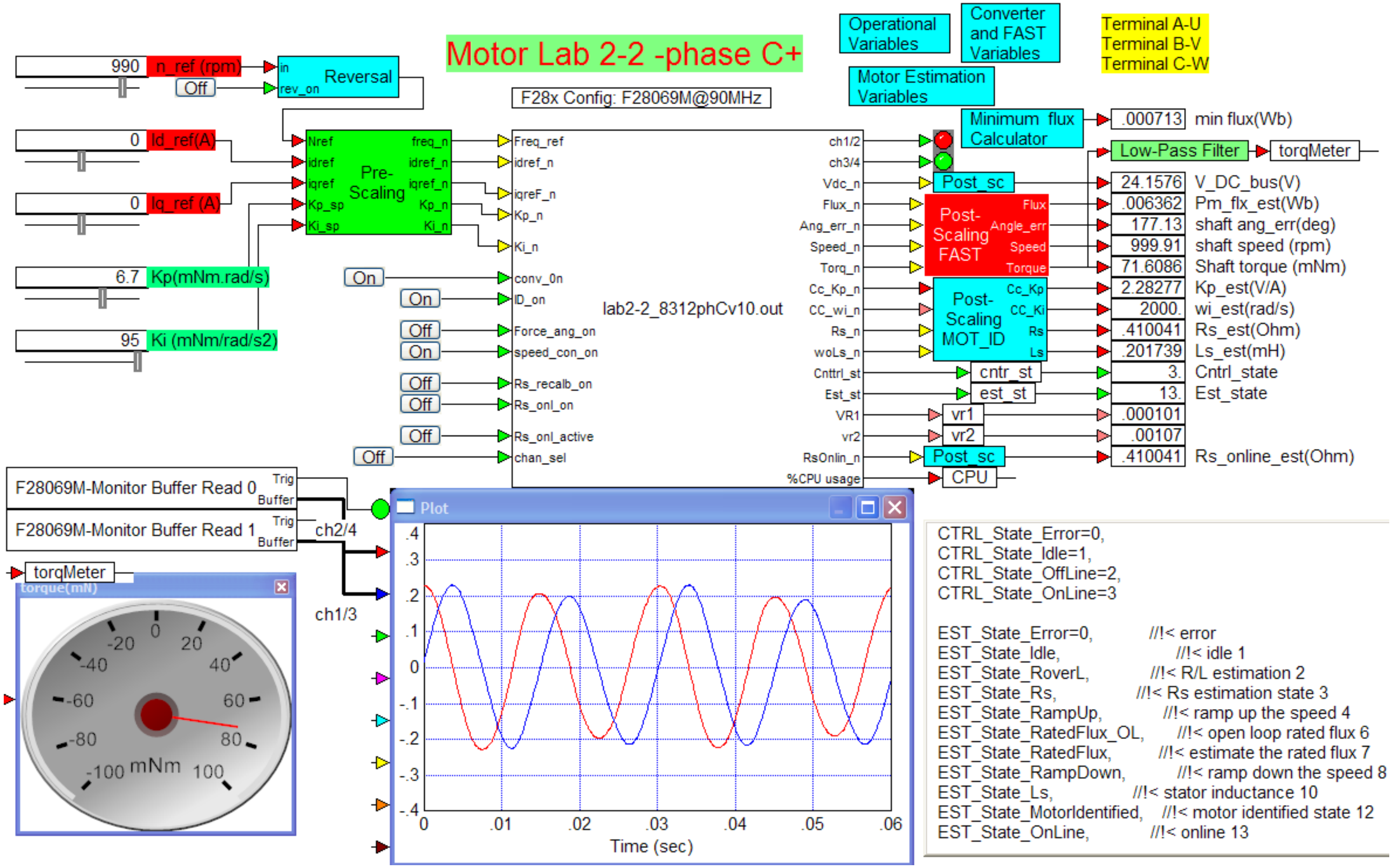
- Example of a VisSim based controller which operates a sensorless drive



➔ Example from Texas Instruments InstaSPIN- VisSim workshop program [5]

InstaSPIN™ development tools

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- Introduction to Texas Instruments MotorWare Software
- Content:

  - Motor Ware software structure
  - InstaSPIN implementation
  - Use of MotorWare to run VisSim lab 2-2 (previous slide) but implementation using CCS instead of VisSim

InstaSPIN™ development tools

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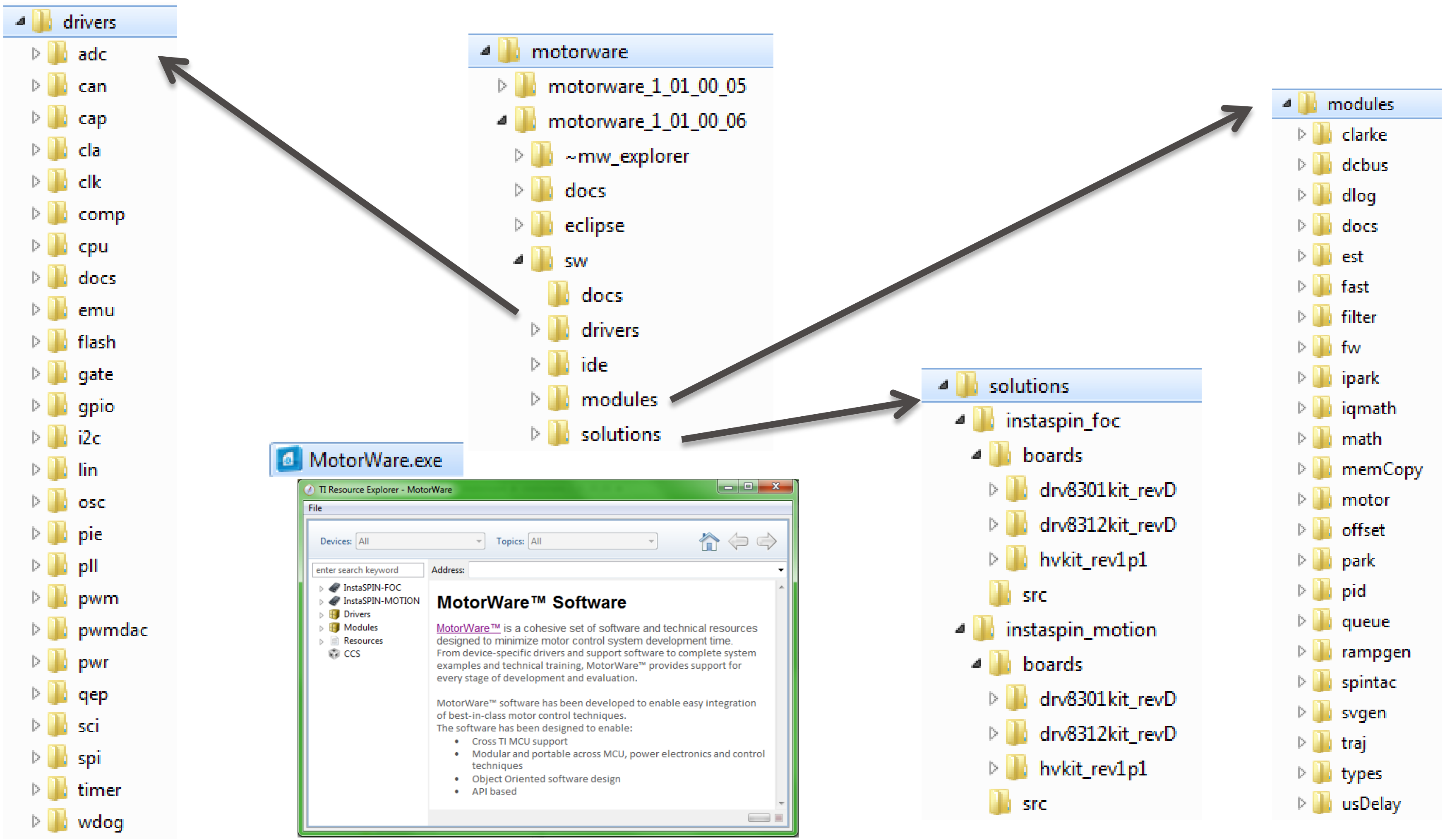
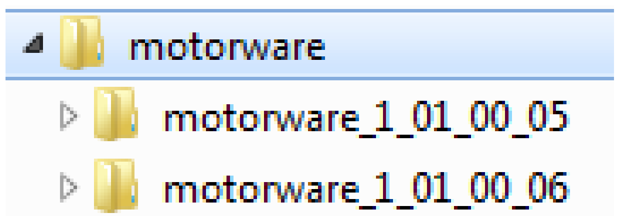
- MotorWare™ is a repository to build solutions:



InstaSPIN™ development tools

- MotorWare™ contains 99% source code
  - ➔ Source: Drivers, Modules, most code used in any solution
  - ➔ Closed source is only some key IP
    - Ex: FAST software sensor (ROM), initial position detection, etc.
- MotorWare™ is under revision and collaboration control using GIT inside TI
- Entire repository is versioned for public release



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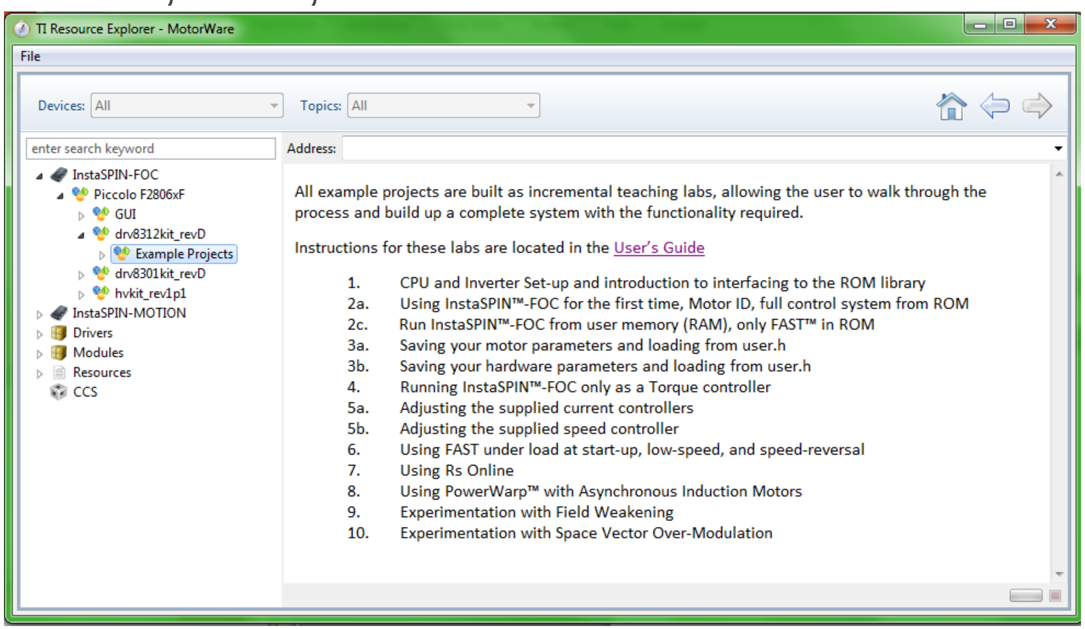
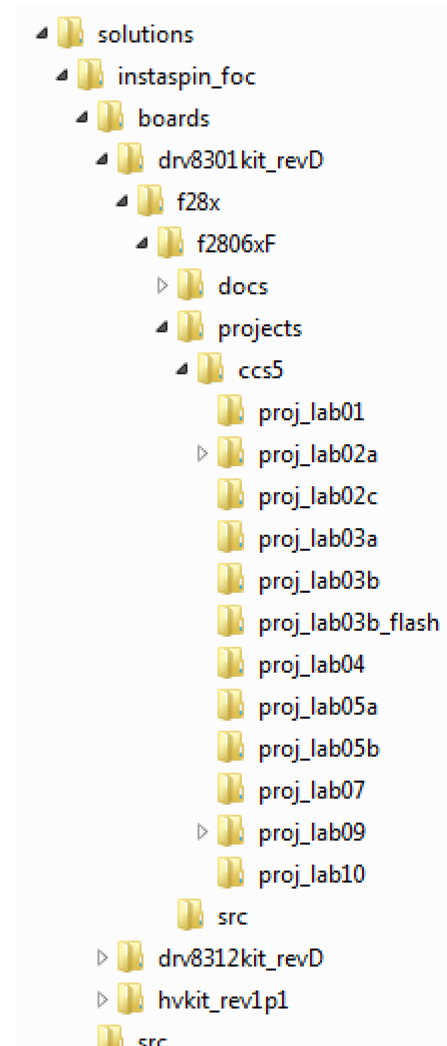
- MotorWare™ contains multiple example projects for each solution
  - ➔ The main proj_lab##.c and ALL other files are *common* through the instaspin_foc solution *across* all boards and MCUs
  - ➔ To port to a new board only three files change: drv.c, drv.h, user.h





- MotorWare™ contains code that produces html documentation using Doxygen

```
//! \brief     Gets the angle value from the estimator in per unit (pu), IQ24.
//! \details   This function returns a per units value of the rotor flux angle. This value wraps around
//!            at 1.0, so the return value is between 0x00000000 or _IQ(0.0) to 0x00FFFFFF or _IQ(1.0).
//!            An example of using this angle is shown:
//! \code
//! _iq Rotor_Flux_Angle_pu = EST_getAngle_pu(handle);
//! \endcode
//! \param[in] handle  The estimator (EST) handle
//! \return    The angle value, pu, in IQ24.
extern _iq EST_getAngle_pu(EST_Handle handle);
```

_iq EST_getAngle_pu (EST_Handle handle)

Gets the angle value from the estimator.

This function returns a per units value of the rotor flux angle. This value wraps around at 1.0, so the return value is between 0x00000000 or _IQ(0.0) to 0x00FFFFFF or _IQ(1.0). An example of using this angle is shown:

```
_iq Rotor_Flux_Angle_pu = EST_getAngle_pu(obj->estHandle);
```

Gets the angle value from the estimator.

Parameters:

[in] *handle* The estimator (EST) handle

Returns:

The angle value, pu, in IQ24.

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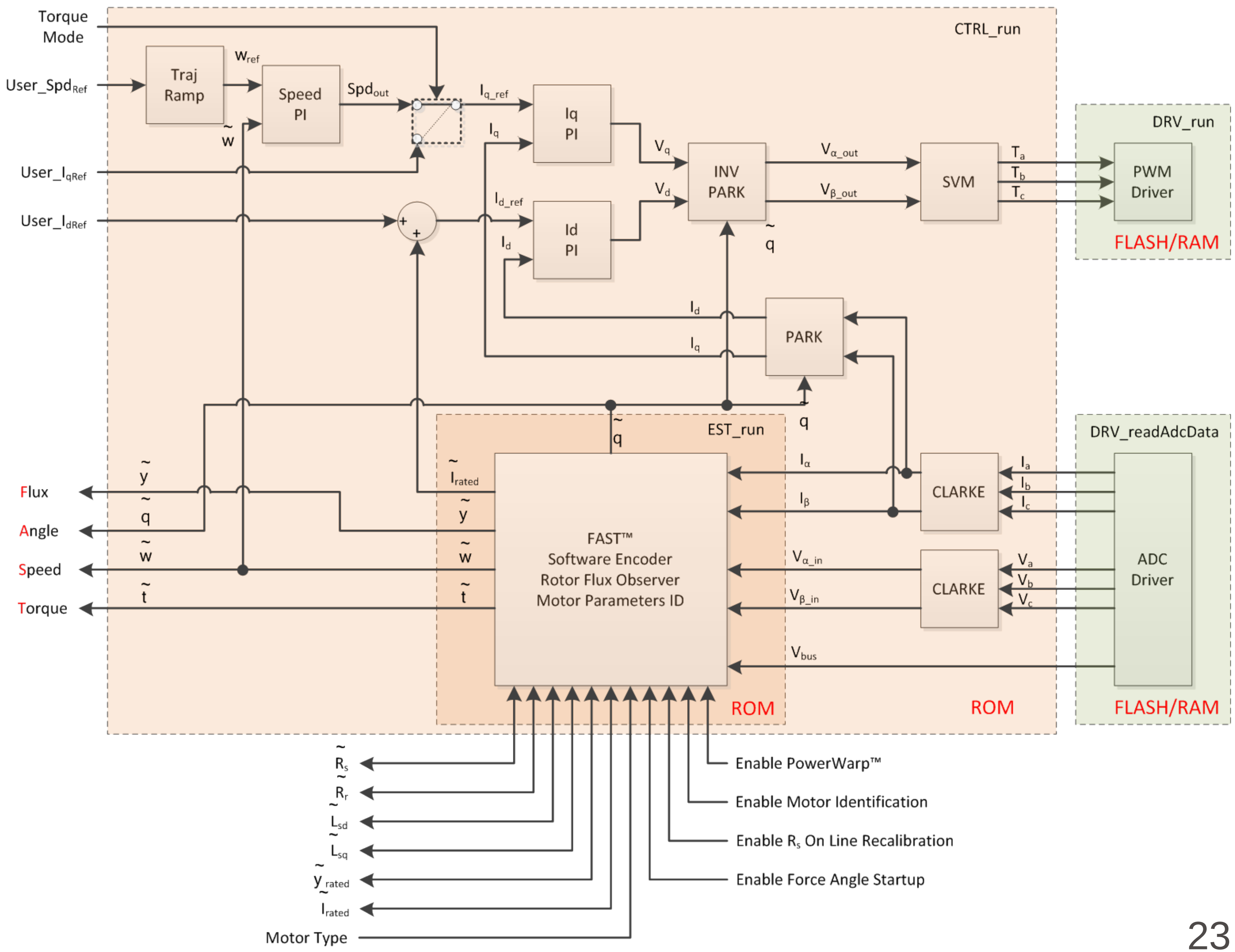
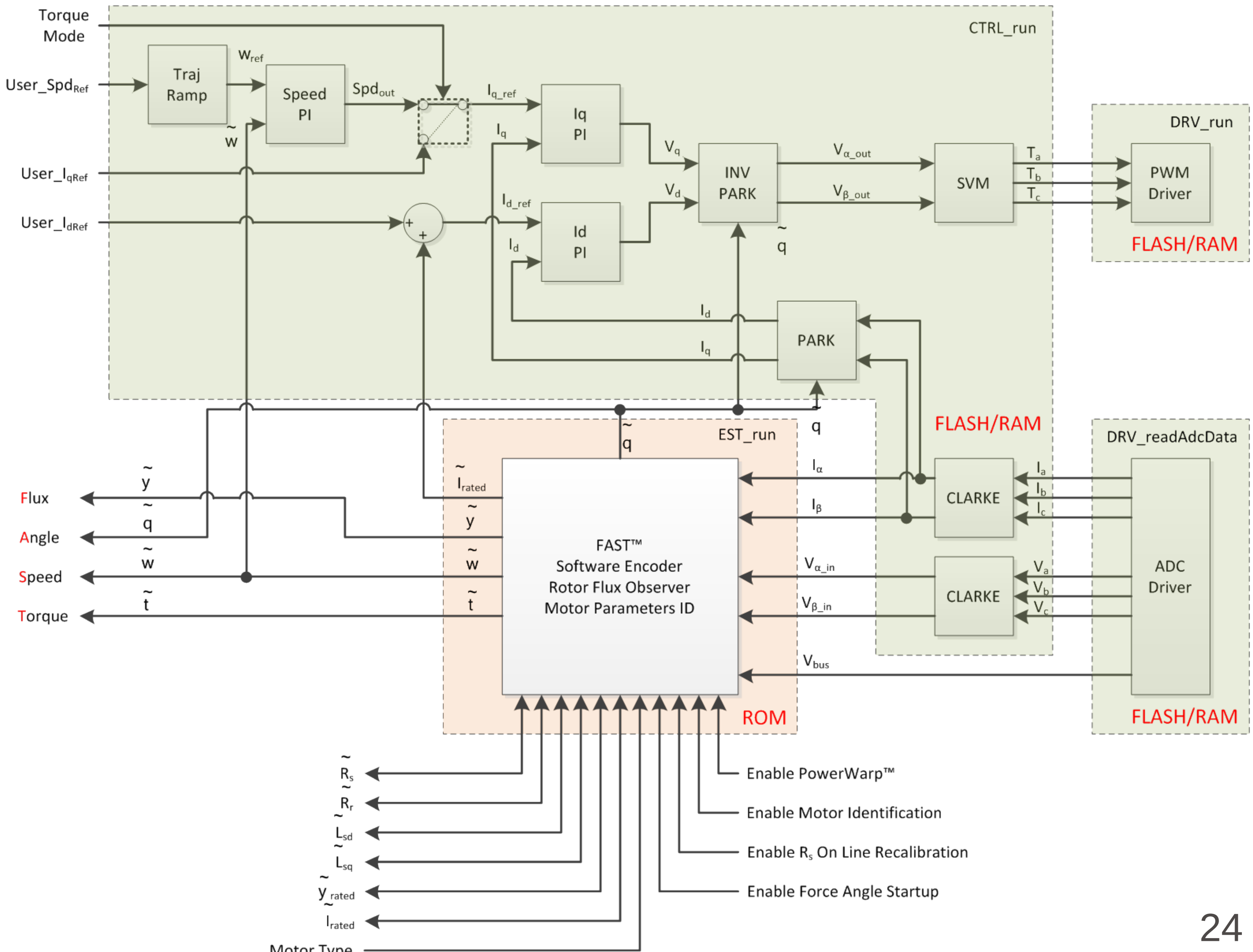
All FOC in ROM



Estimator Only in ROM



InstaSPIN™ development tools

SW Structure

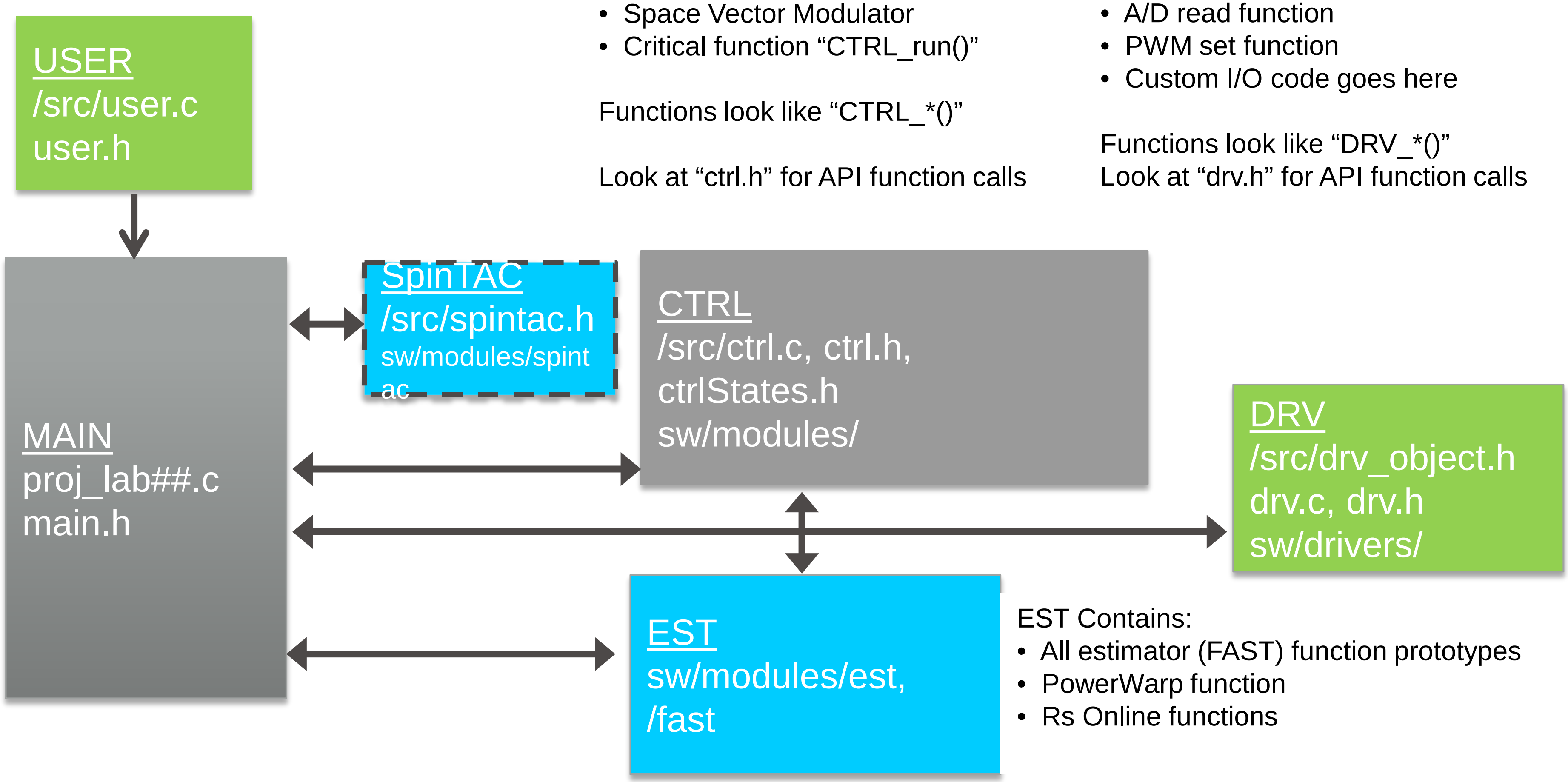
CTRL Contains:
- All PI controllers
- Clarke, Park, Inverse Park
- Space Vector Modulator
- Critical function “CTRL_run()”

Functions look like “CTRL_*()”

Look at “ctrl.h” for API function calls

DRV Contains:
- Inverter/MCU setup/control functions
- A/D read function
- PWM set function
- Custom I/O code goes here

Functions look like “DRV_*()”
Look at “drv.h” for API function calls



EST Contains:
- All estimator (FAST) function prototypes
- PowerWarp function
- Rs Online functions

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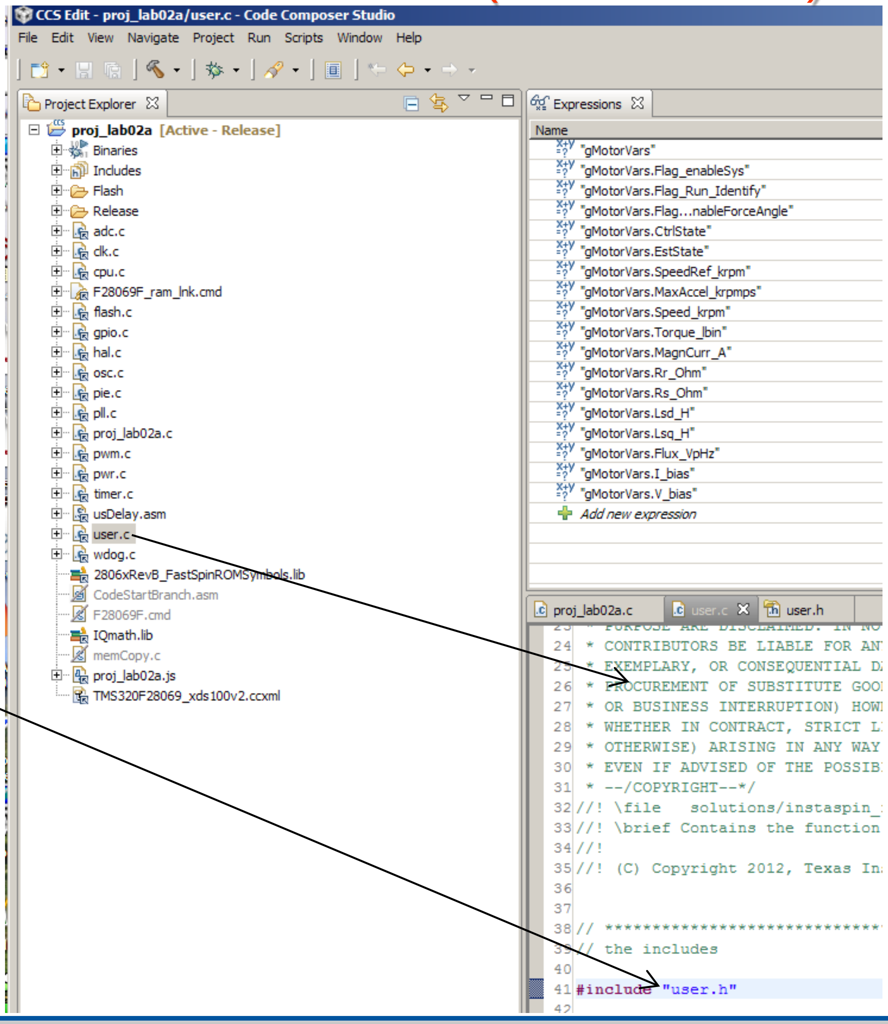
Motor Identification and sensorless operation : Lab 2 MotorWare (lab 2-2 VisSim)

Steps required:

1. Open TI motorware 12
2. Project> Import 'Existing CCS Eclipse project' : need to work down the software tree to find 'lab02a' for DRV8312 board
3. 'right-click' project name and 'rebuild project': result as shown
4. Select (left click) user.c
5. Within user.c select (left click with ctrl down) user.h



Next: configure user.h file according to dialog box data VisSim lab 2-2

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Configure user.h file on the basis of dialog box entries VisSim lab 2-2

User.h MotorWare

user.c | user.h

```
// *****************************************************
// the defines


//! \brief CURRENTS AND VOLTAGES
// *****************************************************
//! \brief Defines the full scale frequency for IQ va
//! \brief All frequencies are converted into (pu) ba
//! \brief this value MUST be larger than the maximum
//#define USER_IQ_FULL_SCALE_FREQ_Hz          (800.0)
#define USER_IQ_FULL_SCALE_FREQ_Hz          (400.0)   /
//! \brief Defines full scale value for the IQ30 vari
//! \brief All voltages are converted into (pu) based
//! \brief WARNING: this value MUST meet the followin
//! \brief WARNING: otherwise the value can saturate
//! \brief WARNING: this value is OFTEN greater than
//! \brief WARNING: if you know the value of your Ben
//! \brief It is recommended to start with a value ~3
//! \brief This value is also used to calculate the m
//#define USER_IQ_FULL_SCALE_VOLTAGE_V        (24.0)
#define USER_IQ_FULL_SCALE_VOLTAGE_V        (48.0)    //
//! \brief Defines the maximum voltage at the input t
//! \brief The value that will be represented by the
//! \brief Hardware dependent, this should be based o
#define USER_ADC_FULL_SCALE_VOLTAGE_V       (66.32)

//! \brief Defines the voltage scale factor for the s
//! \brief Compile time calculation for scale factor
#define USER_VOLTAGE_SF                 ((float_t)((USE

//! \brief Defines the full scale current for the IQ
//! \brief All currents are converted into (pu) based
//! \brief WARNING: this value MUST be larger than th
#define USER_IQ_FULL_SCALE_CURRENT_A            (10.0)
```

lab3-2_8312phCv8.c - Notepad

File Edit Format View Help

User.h compiled in phase C with VisSim

```
/*** VisSim Automatic C Code Generator Version 9.0PR
/*  Output for lab3-2_8312phCv8.vsm at Tue Jul 08 15

#include "math.h"
#include "cgen.h"
#include "cgendll.h"
#include "c2000.h"
#include "MotorWare.h"
#include "DMC32.h"
int MHZ=90;
int curCtlStateGb;
int stateChangeld;
int junk;
DEF_MONITORBUF(_sigBuffer0,901,int,15,3,16);
DEF_MONITORBUF(_sigBuffer1,901,int,15,3,16);
static DRV_PwmData_t gPwmData_0;
static DRV_Obj drvState_0;
static DRV_Handle drvHandle_0;
static DRV_AdcData_t gAdcData_0;
static CTRL_Obj IS_controller_obj0_var;
static CTRL_Obj *IS_controller_obj0=&IS_controller_o
static USER_Params gUserParams_0={10,   /* iqFullSca
48,     /* iqFullScaleVoltage_V */
400,    /* iqFullScaleFreq_Hz */
1,      /* numIsrTicksPerCtrlTick */
1,      /* numCtrlTicksPerCurrentTick */
2,      /* numCtrlTicksPerEstTick */
15,     /* numCtrlTicksPerSpeedTick */
15,     /* numCtrlTicksPerTrajTick */
3,      /* numCurrentSensors */
3,      /* numVoltageSensors */
6.2831853,      /* offsetPole_rps */
628.31853,      /* fluxPole_rps */
0.00125,        /* zeroSpeedLimit */
1,      /* forceAngleFreq_Hz */
4000,   /* maxAccel_Hzps */
20,     /* maxAccel_est_Hzps */
37.699112,      /* directionPole_rps */
314.15927,      /* speedPole_rps */
125.66371,      /* dcBusPole_rps */
1,      /* fluxFraction */
1,      /* indEst_speedMaxFraction */
1,      /* eplGain */
90,     /* systemFreq_MHz */
66.666667,      /* pwmPeriod_usec */
1.3816667,      /* voltage_sf */
1.7277, /* current_sf */
4487.074,       /* voltageFilterPole_rps */
0.92376043,     /* maxVsMag_pu */
1.5,    /* estKappa */
0,      /* motor_type */
```

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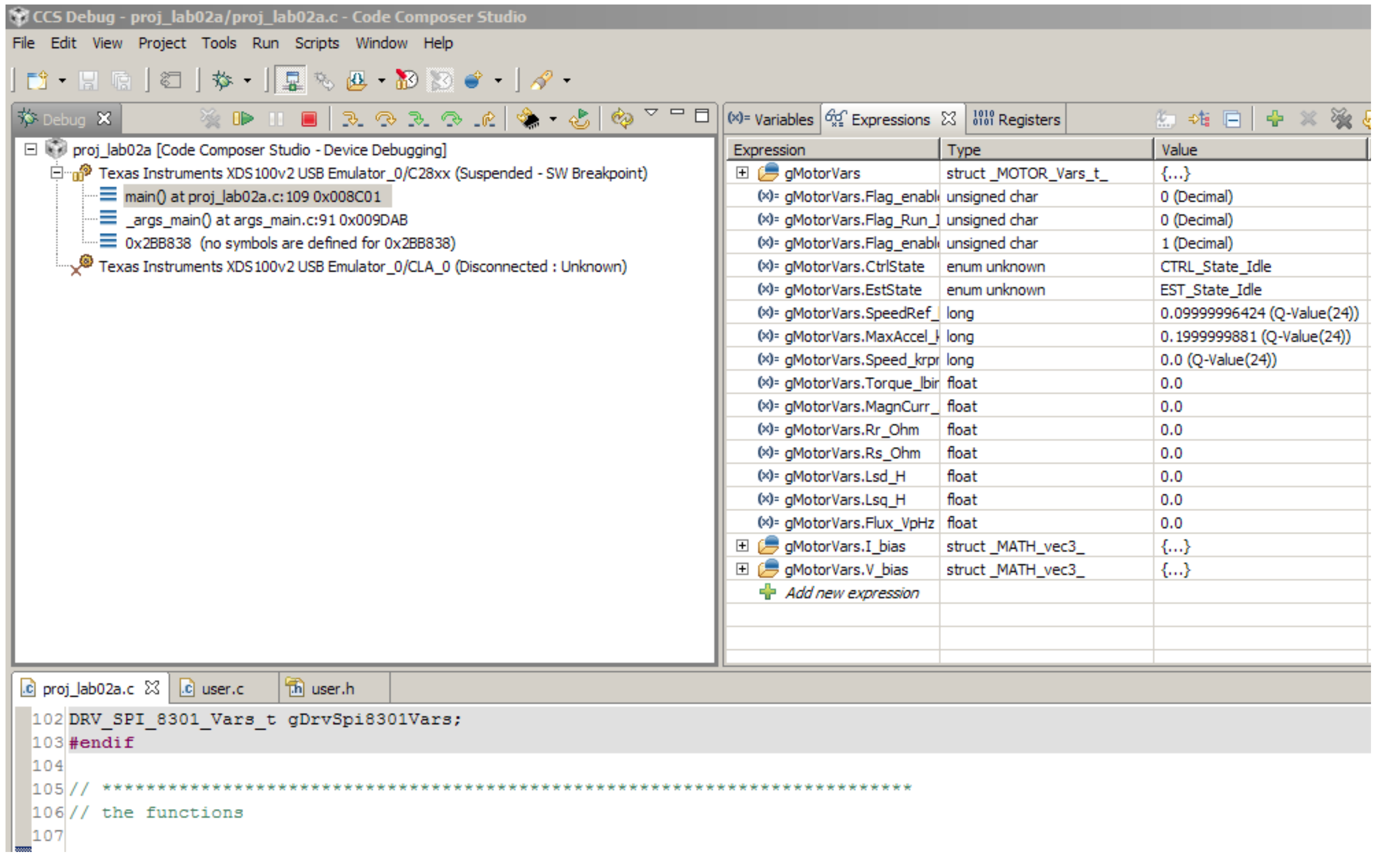
Move to 'debug' mode of CCS to run lab 02a

Green arrow starts debug process:

Flags/variables can be set in Watch window

Output variables shown in Watch (Expression) window during operation. (see next slide)



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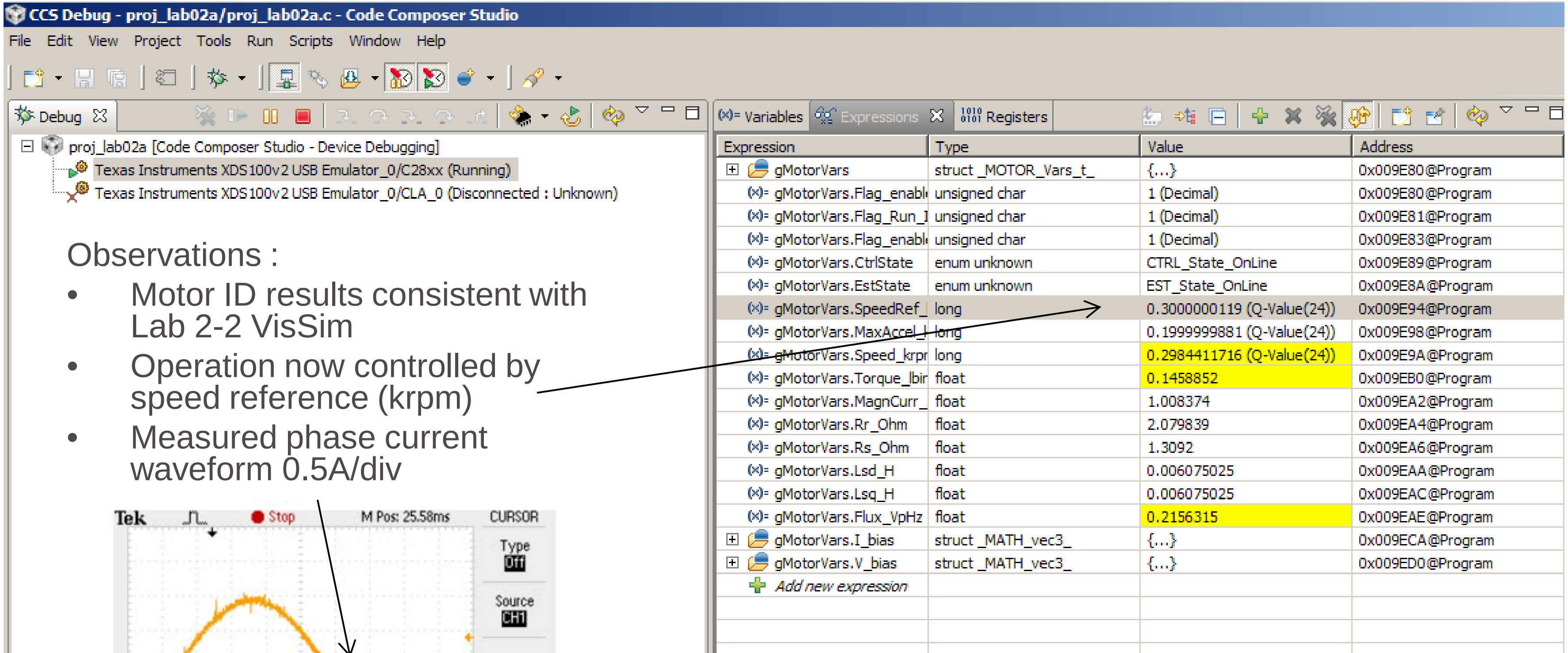
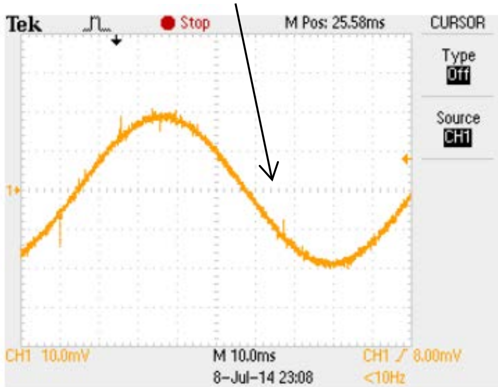
'Debug' mode during operation:



Expression	Type	Value	Address
gMotorVars	struct _MOTOR_Vars_t_	{...}	0x009E80@Program
gMotorVars.Flag_enabl	unsigned char	1 (Decimal)	0x009E80@Program
gMotorVars.Flag_Run_I	unsigned char	1 (Decimal)	0x009E81@Program
gMotorVars.Flag_enabl	unsigned char	1 (Decimal)	0x009E83@Program
gMotorVars.CtrlState	enum unknown	CTRL_State_OnLine	0x009E89@Program
gMotorVars.EstState	enum unknown	EST_State_OnLine	0x009E8A@Program
gMotorVars.SpeedRef_	long	0.3000000119 (Q-Value(24))	0x009E94@Program
gMotorVars.MaxAccel_	long	0.1999999881 (Q-Value(24))	0x009E98@Program
gMotorVars.Speed_krpr	long	0.2984411716 (Q-Value(24))	0x009E9A@Program
gMotorVars.Torque_lbir	float	0.1458852	0x009EB0@Program
gMotorVars.MagnCurr_	float	1.008374	0x009EA2@Program
gMotorVars.Rr_Ohm	float	2.079839	0x009EA4@Program
gMotorVars.Rs_Ohm	float	1.3092	0x009EA6@Program
gMotorVars.Lsd_H	float	0.006075025	0x009EAA@Program
gMotorVars.Lsq_H	float	0.006075025	0x009EAC@Program
gMotorVars.Flux_VpHz	float	0.2156315	0x009EAE@Program
gMotorVars.I_bias	struct _MATH_vec3_	{...}	0x009ECA@Program
gMotorVars.V_bias	struct _MATH_vec3_	{...}	0x009ED0@Program
Add new expression			

Observations :

- Motor ID results consistent with Lab 2-2 VisSim
- Operation now controlled by speed reference (krpm)
- Measured phase current waveform 0.5A/div



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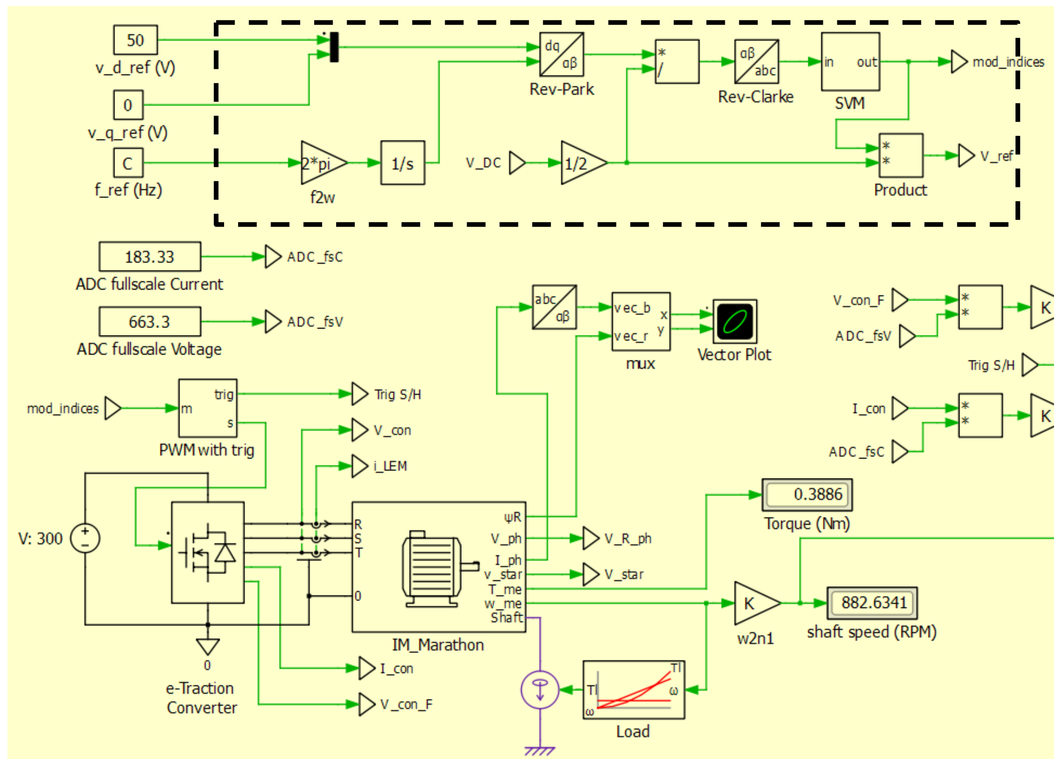
PLECS simulation software:

What is PLECS [6]? :

- Comprehensive software development platform which is available as 'stand-alone' or with MATLAB/Simulink
- Ability to use Electrical and control blocks together
- Example PLECS: Case3av2 V/f controller with e-Traction converter and IM motor

Example:

- V/f controller
- SVM modulator
- PWM
- ADC with Sampling
- Converter with ideal or non ideal power electronic devices
- Thermal modelling converter (heat sink)
- Motor model
- Mechanical model interfaces to load
- Comprehensive analysis tools
- Fast computation times



PLECS model

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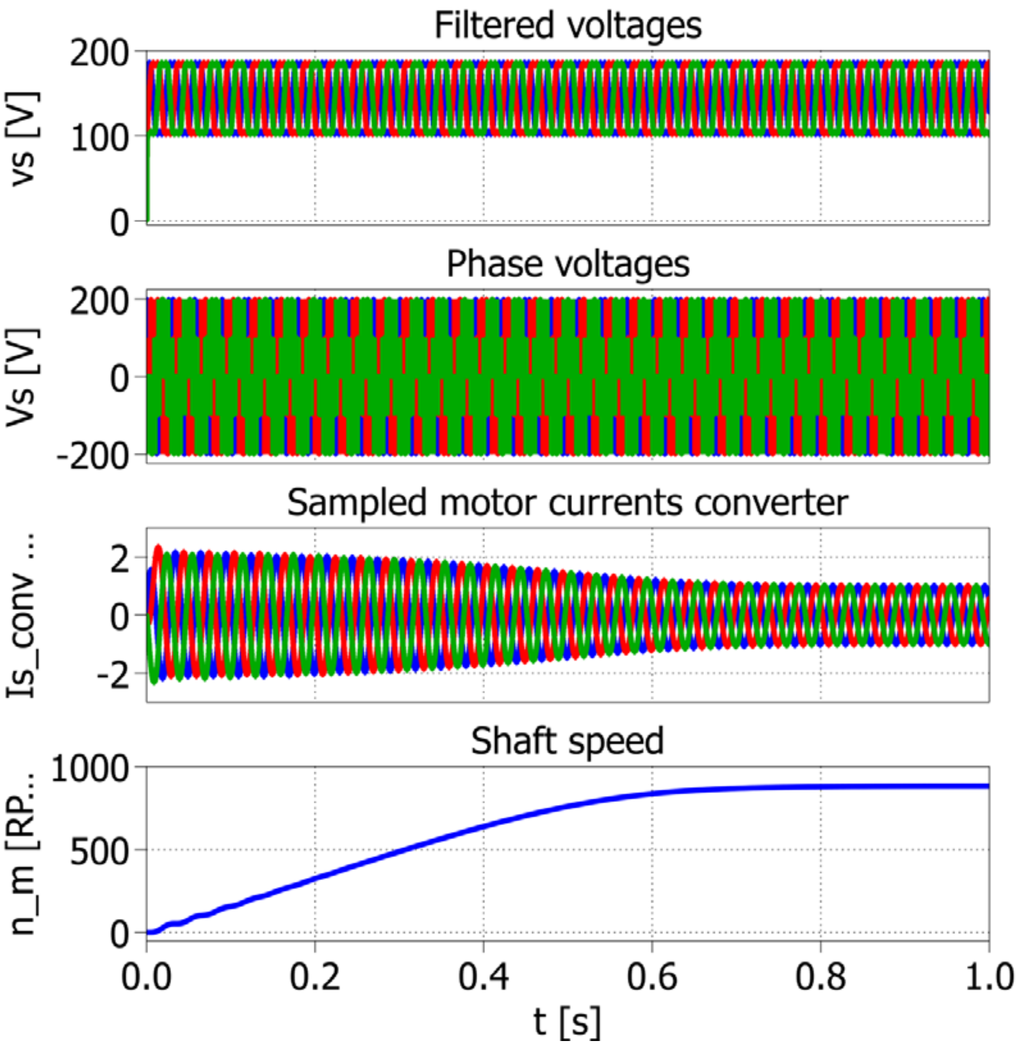
PLECS simulation software:

- V/f controller
- Typical results :



User has the ability to fully tailor drive design to meet performance requirement

PLECS software

- Example PLECS case study
- e-Traction 3 kW/400V converter and Marathon IM motor
- SETUP in use with:
  - **TMS32028069M control card with USB JTAG interface located on e-Traction board**
  - **400V/2 A DC power power supply**
  - **24V auxiliary power supply for logic circuit**
  - **CAN BUS interface (not used here)**
- We want to evaluate sensorless operation WITHOUT running the hardware
- Answer: PLECS processor in the loop technology (PIL)

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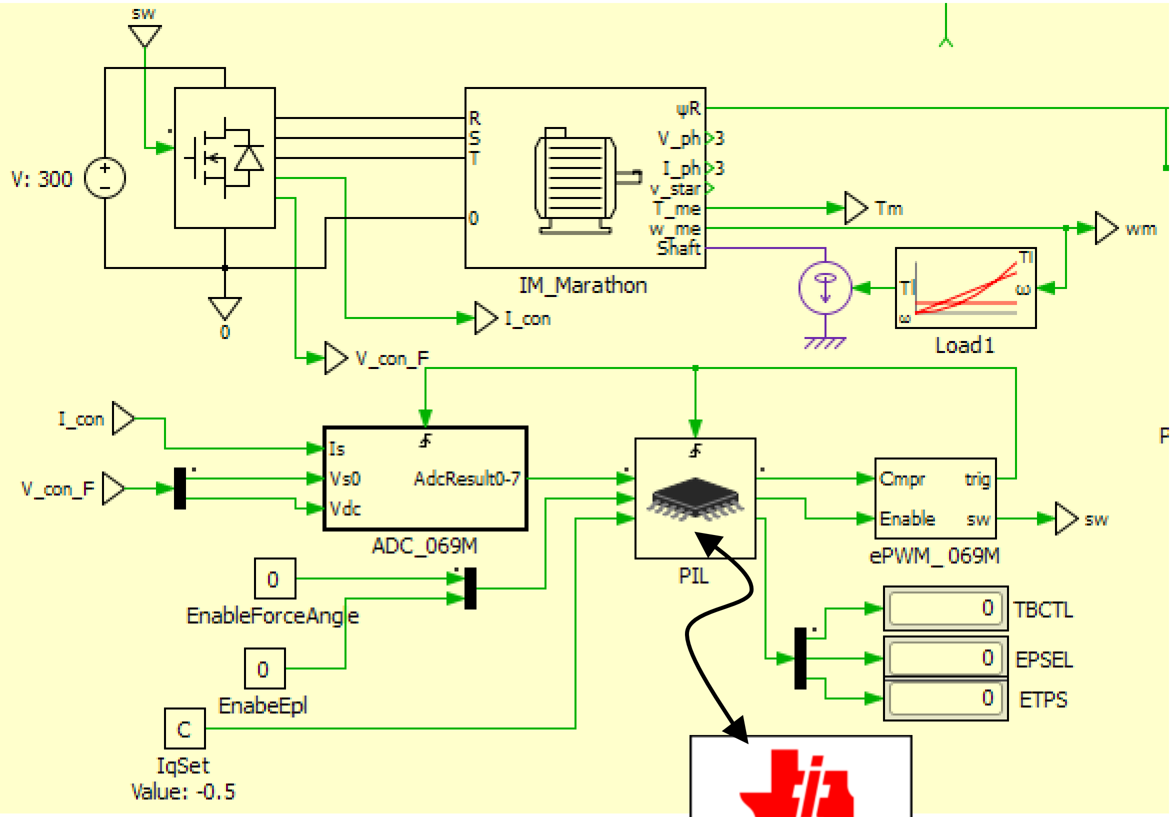
PIL: 'Processor in the loop'

What is PIL ?

- TMS320F8069M processor in the 'loop'
- ADC inputs from hardware 'overridden' by inputs from 'ADC-069M' PLECS module
- PWM outputs 'sw' by MCU now generated by 'ePWM_069M' PLECS module, which controls PLECS converter
- MCU 'trig' output used to trigger internal ADC now triggers PLECS 'ADC-069M'
- Additional inputs/outputs to PIL can be generated to suit user requirements.
- MCU runs the TI MotorWare labs, provided they are 'PIL prepared'
- In this example MotorWare laboratory 4e is used to control the drive: FAST as encoder, with known parameters and control of 'IqSet' (reference Iq)



Next: how to set up PIL operation

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How to set up PIL operation

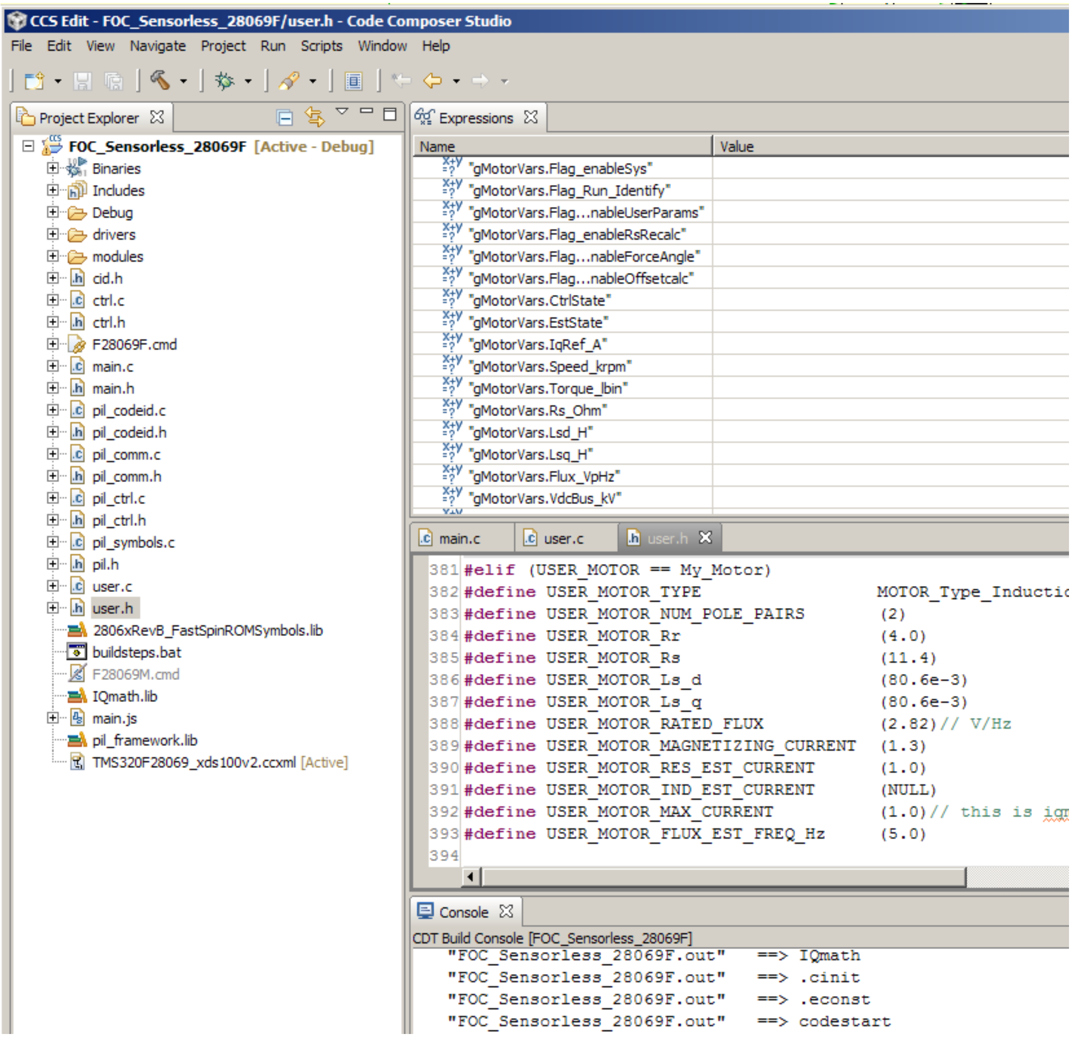
Actions to take:

- Import the PLECS PIL prepared MotorWare lab 4e
- Edit the user.h file to match the motor and drive data used in PLECS model.
- Edit drv.c if the MCU clock freq. need to change as is the case here: set to 60 MHz
- Rebuild the project, which generates a xxx. out file
- Keep the MotorWare and PLECS file in the same folder
- Move to 'Debug' mode and which downloads

  xxx.out file

- Start debug : LED flashing on control board

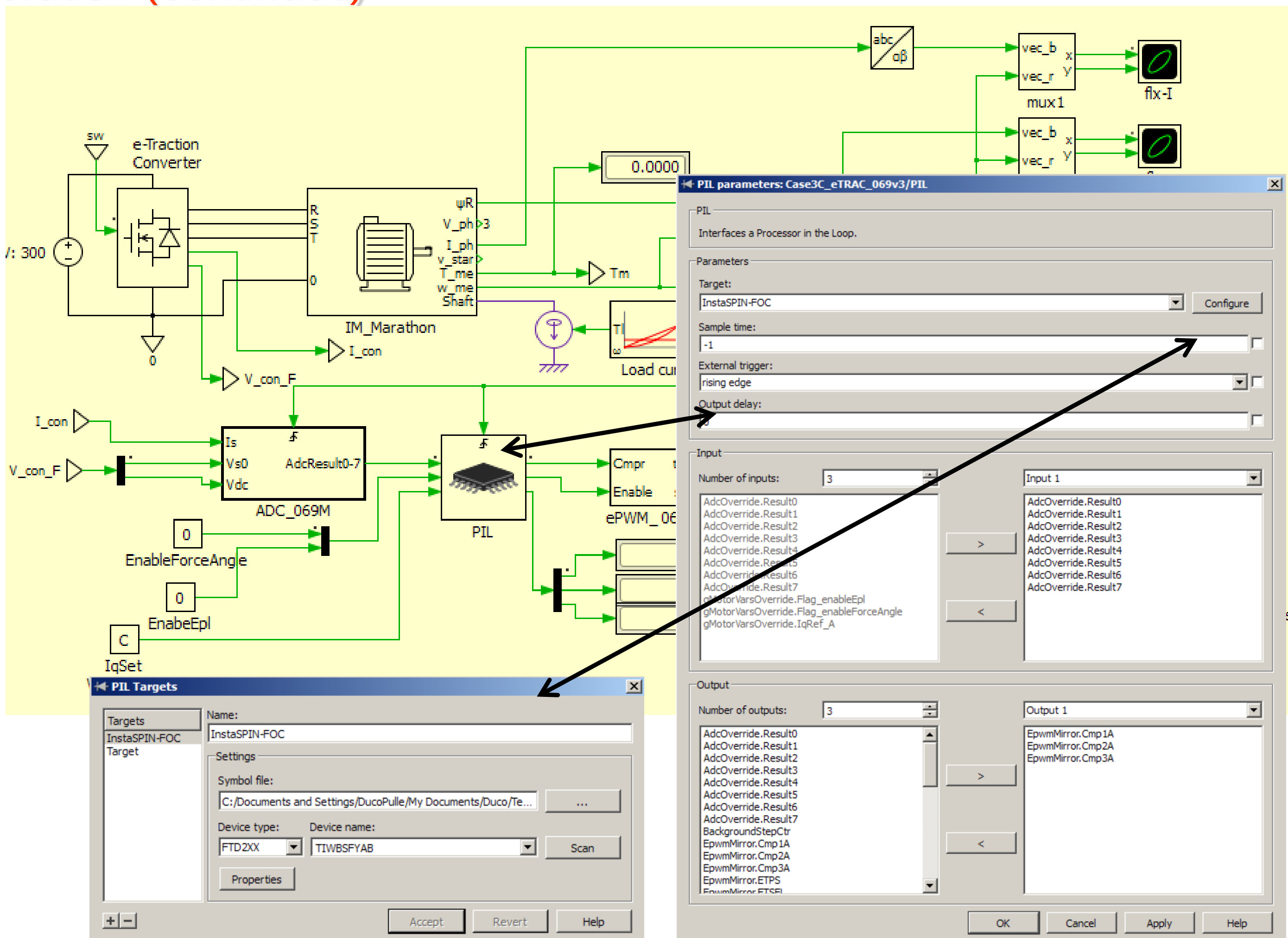
Next: move to the PLECS model



How to set up PIL operation (continued)

Actions to take:

- Double left click on PLECS PIL
- Set target to InstaSPIN-FOC
- Select 'configure'
- Enter the location of for the xxx. out in the 'symbol' entry
- Entries for the ePWM-069M must be made, but requires one time PIL operation so that info is on displays.
- In PLECS Simulation parameters> Initialization box: set System CLK and PWM frequency



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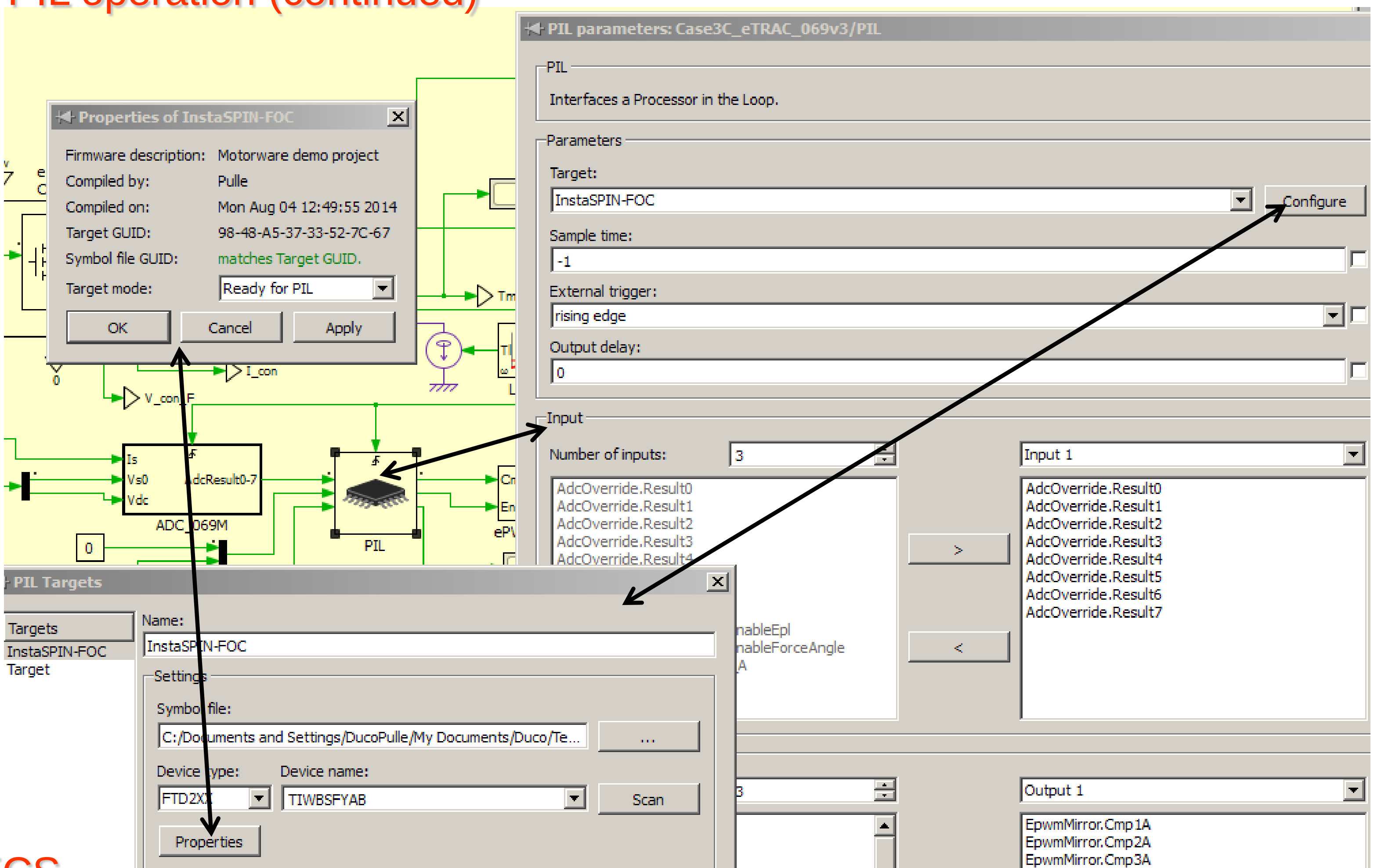
How to set up PIL operation (continued)

Actions to take:

- Click on PLL
- Select 'Configure'
- Select 'Properties'
- Confirm that symbol file GUID states 'matches Target GUID'
- Check that 'Target mode' set to 'ready for PIL'



Next: RUN PLECS

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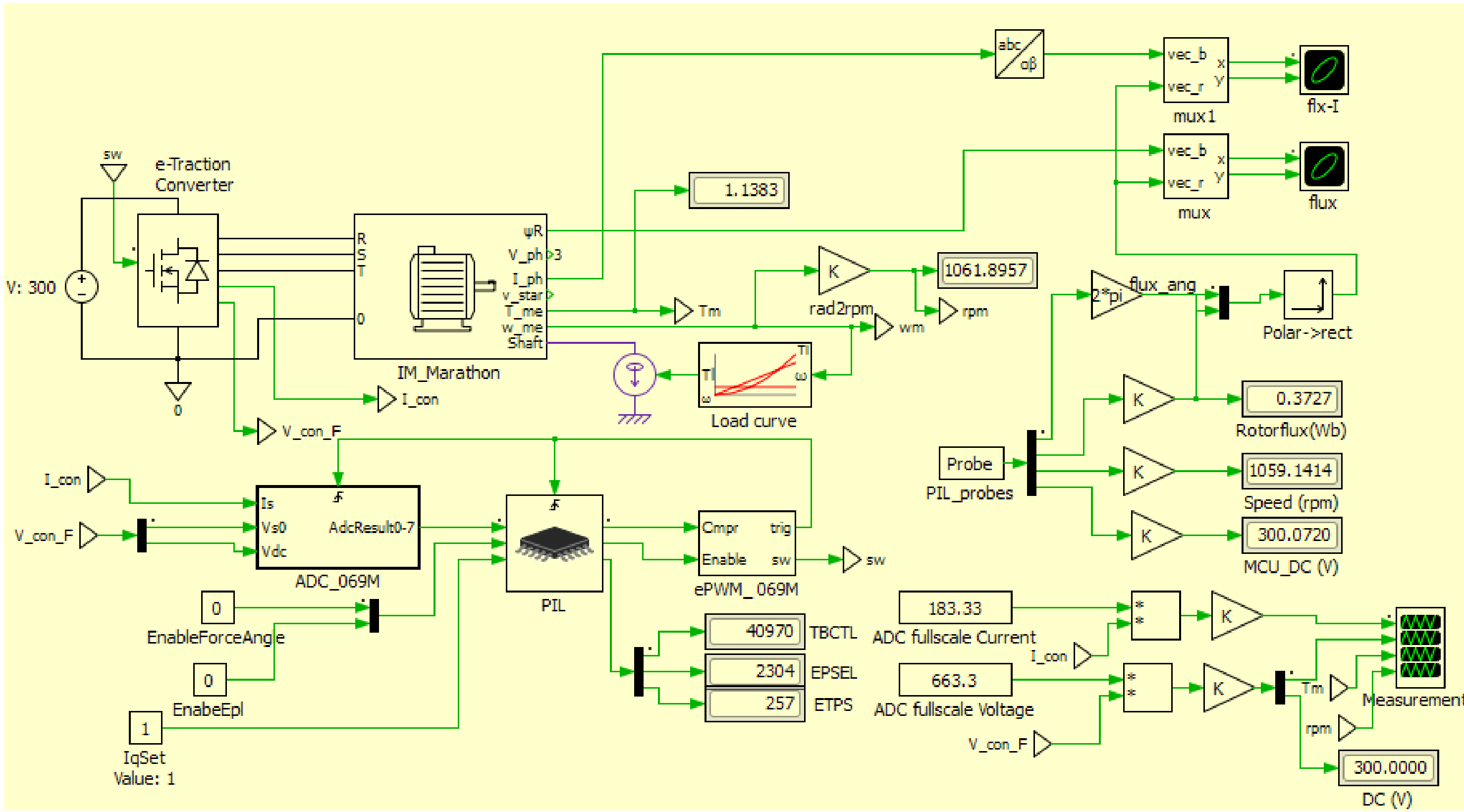
Running PIL

Actions to take:

- Set 'enable force angle 1'
- set iqSet to 1 A
- We have quadratic load curve 1 Nm at 1000 rpm
- Start PLECS
- Observe:
  - MCU DC is 300V
  - check TBCL, EPSEL and ETPS match results in ePWM mod
- Selected magnetizing current Id=1.3A corresponds to rotor flux of 0.37Wb

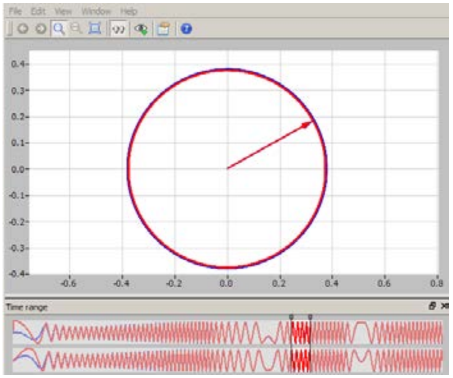


Next: Results achieved with PIL

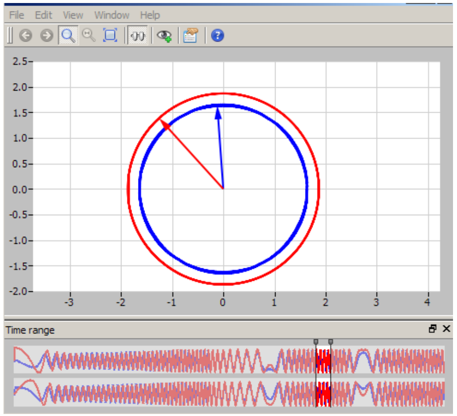
Results when Running PIL with PLECS

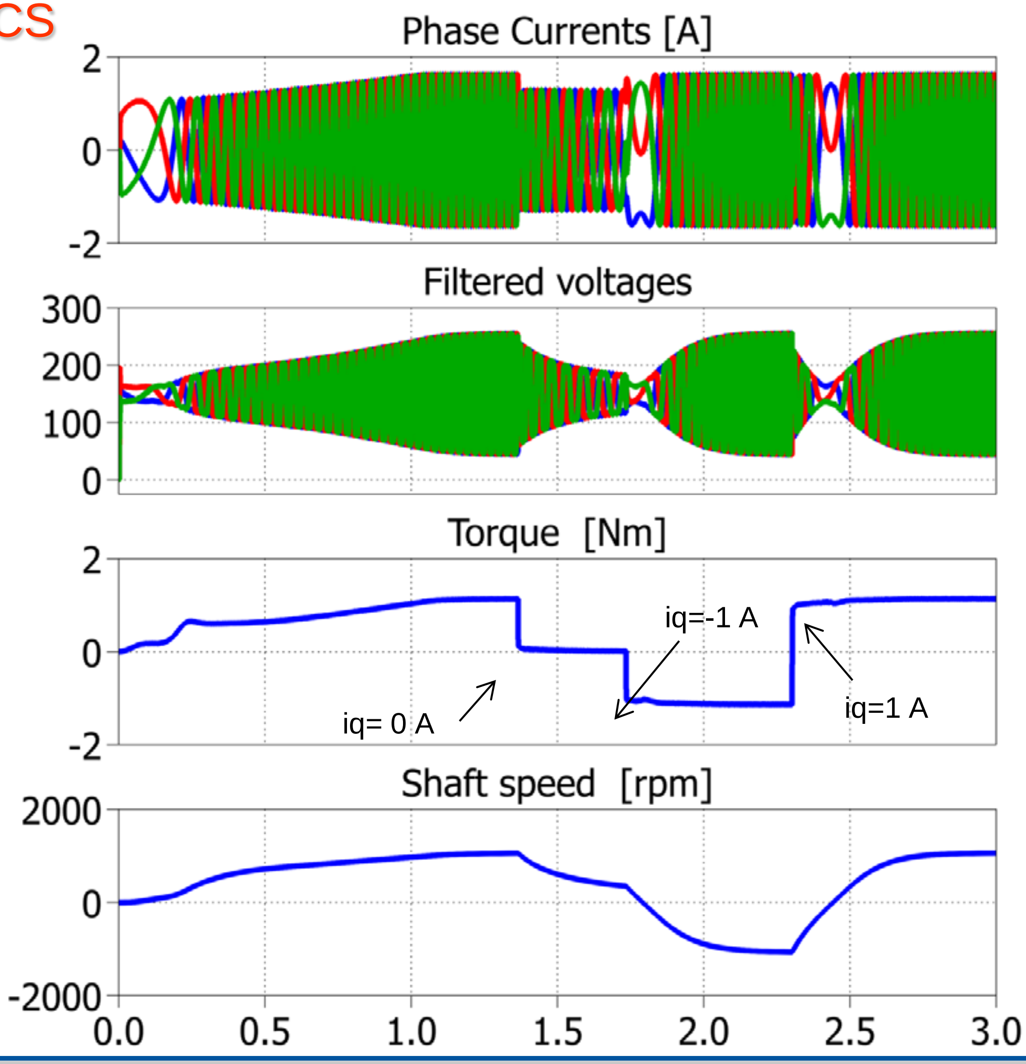
Observations:

- Machine fully fluxed at t=1.2s (force angle turned off)
- Actual and FAST (red) flux vectors aligned



- FOC torque control example :
  - flux times 5 (red) and current vector





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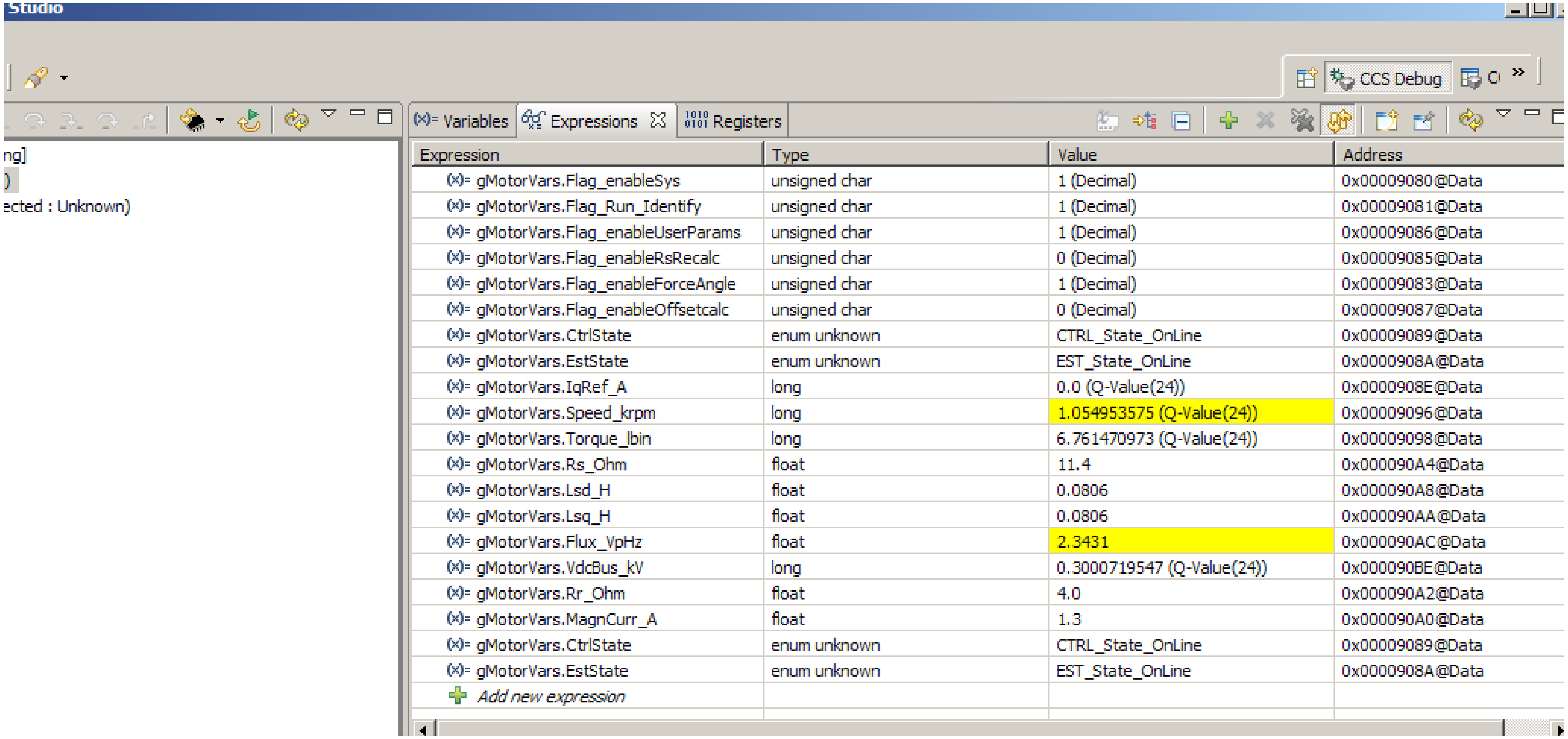
Result when Running PIL with CCS



Expression	Type	Value	Address
gMotorVars.Flag_enableSys	unsigned char	1 (Decimal)	0x00009080@Data
gMotorVars.Flag_Run_Identify	unsigned char	1 (Decimal)	0x00009081@Data
gMotorVars.Flag_enableUserParams	unsigned char	1 (Decimal)	0x00009086@Data
gMotorVars.Flag_enableRsRecalc	unsigned char	0 (Decimal)	0x00009085@Data
gMotorVars.Flag_enableForceAngle	unsigned char	1 (Decimal)	0x00009083@Data
gMotorVars.Flag_enableOffsetcalc	unsigned char	0 (Decimal)	0x00009087@Data
gMotorVars.CtrlState	enum unknown	CTRL_State_OnLine	0x00009089@Data
gMotorVars.EstState	enum unknown	EST_State_OnLine	0x0000908A@Data
gMotorVars.IqRef_A	long	0.0 (Q-Value(24))	0x0000908E@Data
gMotorVars.Speed_krpm	long	1.054953575 (Q-Value(24))	0x00009096@Data
gMotorVars.Torque_lbin	long	6.761470973 (Q-Value(24))	0x00009098@Data
gMotorVars.Rs_Ohm	float	11.4	0x000090A4@Data
gMotorVars.Lsd_H	float	0.0806	0x000090A8@Data
gMotorVars.Lsq_H	float	0.0806	0x000090AA@Data
gMotorVars.Flux_VpHz	float	2.3431	0x000090AC@Data
gMotorVars.VdcBus_kV	long	0.3000719547 (Q-Value(24))	0x000090BE@Data
gMotorVars.Rr_Ohm	float	4.0	0x000090A2@Data
gMotorVars.MagnCurr_A	float	1.3	0x000090A0@Data
gMotorVars.CtrlState	enum unknown	CTRL_State_OnLine	0x00009089@Data
gMotorVars.EstState	enum unknown	EST_State_OnLine	0x0000908A@Data
Add new expression			

Observations from Watch Window :

- Shows the machine parameters in use and magnetizing current selected
- Shows rotor flux (V/Hz) of the estimator, rotor speed (krpm) and supply voltage

Control of drive may also be realized directly from CCS watch window by setting PIL to 'normal operation'

Applications of sensorless control

- Why customers change to Sensorless control using InstaSPIN?
  - To reduce product cost : removal of the encoder leads to significant savings
  - To reduce product development time
  - To increase reliability: to avoid encoder alignment and breakdown problems
  - To enhance their product: having access to instantaneous shaft torque and speed   without requiring additional (to the power leads) is attractive
  - Ability to   measure and track key motor parameters: measurement of, for example, resistance gives the ability to monitor temperature of the motor
  - Need for sophisticated motion control: use of SpinTAC [7] control suite
  - To provide back up to encoder based drives: provides the ability to keep the drive in operation if an encoder related problem occurs
  - To improve energy efficiency: for drive which use an induction machine, which allows field weakening during partial load operation

➔ Application examples

Applications of sensorless control

- Application examples: currently in use or being developed

PUMPS

Automotive	Industrial/Consumer
•Transmission •Brake/Boost •Oil •Turbo •Fuel/Water	•Constant pressure •Water/Waste/Chemical •Spa/pool pump •Geothermal pump •Dishwashers

COMPRESSORS

Automotive	Industrial/Consumer
•Refrigeration	•Air/Con •Refrigeration

LAUNDRY

•Washers
•Dryers

BLOWERS/FANS

Automotive	Industrial/Consumer
•Air/Con Blowers •Cooling Fan	•Respiratory •Vacuum •Fans •Air/Con Blowers •Exhaust

HIGH TORQUE

Transit	Conveyors
•Traction •eBike/Moped/Scooter •Off-highway Vehicles •Carts, Transport •Fork lifts •Wheel chairs	•Escalators •Elevators •Treadmill •Tools •AC Drive / Inverter •Assembly Line

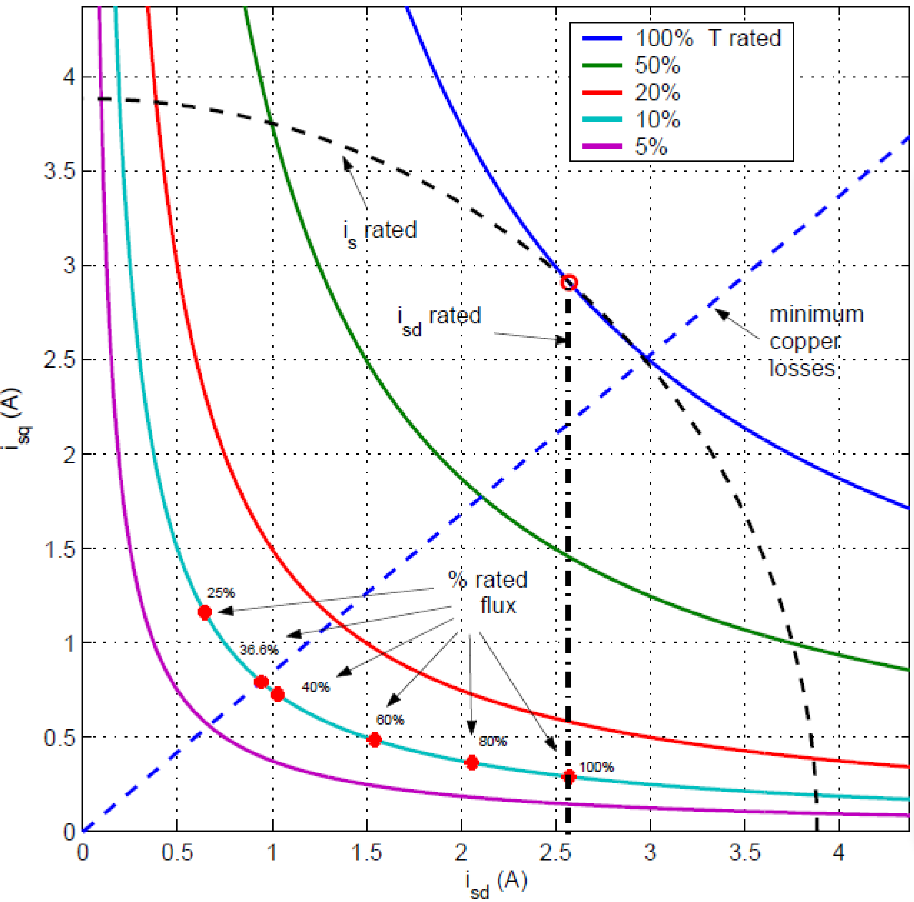
Applications of sensorless control

- Specific application examples: Traction drive for Electric Vehicle

  - Use of InstaSPIN-FOC to realise a highly responsive & efficient torque machine like this high performance 'Tesla'

Applications of sensorless control

- Specific application examples: Induction machine drives using PowerWarp



Adaptively reduce magnetizing current to only induce the field required for the torque required!

Real World Field Trial

Induction Motors used for Agriculture Air & Humidity Control

PowerWarp Savings

80% of energy vs. Traditional Triac

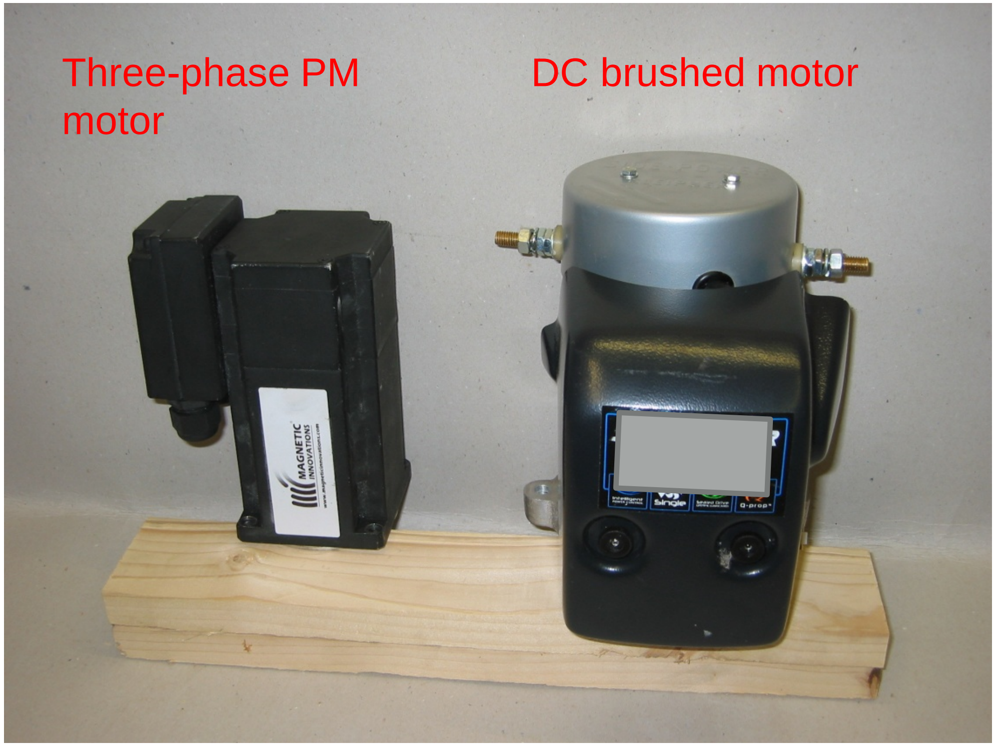
45% of energy vs. IS-FOC

Algorithm is based on reducing motor copper losses in the stator AND the rotor!

www.ti.com/powerwarp

Applications of sensorless control

- Specific application examples: Bow thruster for yacht



Max power: 3500W
Speed: 6000 rpm
Max current: 15 A
Efficiency : 90%
Weight: 3.5 kg

Max power: 2200W
Speed: 4100 rpm
Max current: 280 A
Efficiency : 75%
Weight: 8.9 kg

Summary/comments

- Introduction on sensorless electrical drive technology:
- Challenges faced when trying to implement a sensorless drive
- Introduction on the InstaSPIN Sensorless solution
- Introduction of development tools that can be used to speed up and simplify the development of MCU based control in general and InstaSPIN in particular
- Overview of InstaSPIN based applications currently in placed and those being developed world wide
- Book 'Embedded control of Electrical Drives using VisSim and PLECS' to appear later this year (publisher Springer)
- Demo table at conference which shows InstaSPIN in action!

Thank you for your attention !

References

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3. Texas Instruments InstaSPIN: www.ti.com/instaspin
4. VisSim: www.vissim.com
5. C2000 based 2-Day Hands-On Motor Control Workshops
6. PLEXIM: www..plexim.com
7. SpinTAC motion control suite: part of InstaSPIN-Motion control

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Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265