Figure 1: MACCON SRC4/300-05 Switched Reluctance Controller

The SRC4/300-05 is a state-of-the-art controller for Switched Reluctance Motors (SRM). It brings together the intelligence and capability of FPGAs with IGBT power device technology in one smart and compact drive for the control of switched reluctance machines.

The Switched Reluctance Controller is intended for laboratory use to test 2 to 4 phase SRMs up to 300Vdc nom. voltage, primarily in the standard, block current mode. It allows for the free definition of current switching angles, supported by incremental encoder feedback. In the final application Hall-effect or other simple feedback sensors may be used instead of an encoder.

Main Features:

- Compatible with 2-, 3- and 4-phase SRMs
- Block current commutation, switched at user-set Turn-on and Turn–off angles
- Interface for incremental encoder (5V, TTL)
- Full 4-quadrant operation in current/torque or speed control mode
- DC-Link supply voltage range of 24 to 350Vdc
- Rated continuous phase current of 5Arms
- Peak phase current of 15Arms for 1.5 secs
- 20 KHz PWM switching frequency
- Under- and overvoltage, I²t-current protection; overcurrent monitor with disable
- Extension interface for external chopper for dissipation of regenerative energy
- Fully configurable PC control, via RS232, SRC-MON PC-software supplied
- Switch to allow enabling or disabling of system via logic (aux. power remains active)
- LED indicators for: aux. power, main power and Enable condition

SPECIFICATION

Parameter	Value	Unit
Auxiliary power supply voltage, external (15W)	24 (18-36)	Vdc
Rated DC-Link voltage	300	Vdc
DC-Link peak voltage (max.)	350	Vdc
Undervoltage enable/disable voltage (auxiliary supply)	16	Vdc
Overvoltage disable voltage (DC Link) – controlled by software	380	Vdc
Isolation between power and control circuits - DC-Link and GND (+/-) and heat-sink; isolation test 2,000VDC/1s	400	Vdc
Overcurrent threshold (no overcurrent, short-circuit protection)	25	A
Maximum continuous phase current, vertical mounting and natural convection.	5	Arms
Peak DC phase current for 1,5s (max. duty cycle 5%)	15	Arms
Maximum switching frequency	20	kHz
Maximum DC-Link voltage slope dV/dt	1	V/ms
Number of phase-outputs	2-4	
Ambient temperature range (10-80% RH)	0 - 60	°C
Storage temperature range	-20 - 80	°C
IP protection class	IP20	
Communication interface to Host Computer	RS232	

GENERAL SYSTEM DESCRIPTION

The SRC consists of a Power Stage, which feeds the phases of a Switched Reluctance Motor (SRM) directly and a state of the art, FPGA-based controller board.
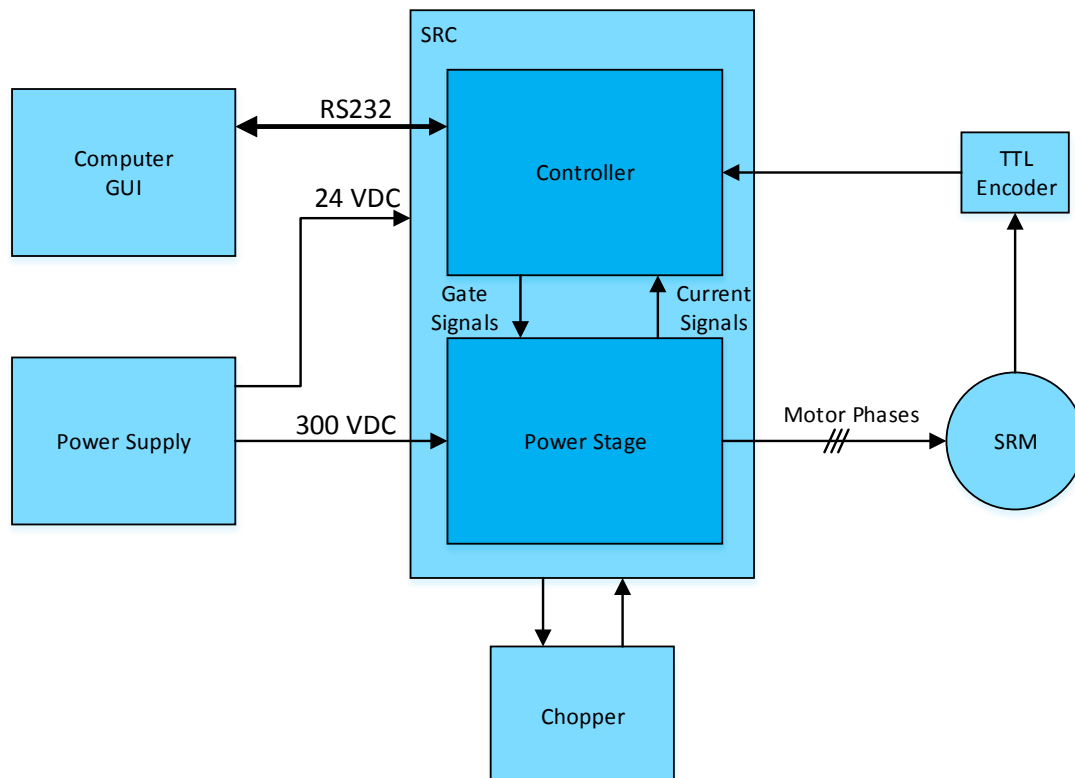
Figure 2: Simplified diagram of the SRC system

The Control Unit requires an auxiliary supply voltage of 24 VDC. The user can communicate with the SRC4/300-05 from a Personal Computer through the RS232 connection, using the PC Software provided

SRC-MON".

The Power Stage of the SRC4/300-05 uses robust asymmetric H-bridges, which are switched with PWM. The input voltage can be provided from a DC supply or by simple rectification of an AC supply (with potential isolation to mains; e.g. by means of a transformer). The Power Stage features and phase current, DC-Link voltage and heat sink temperature monitoring. Hardware protection is provided against phase I²t- and overcurrent as well as DC-Link overvoltage of the auxiliary converter.

The basic controller does not have an integrated regeneration energy dump in the case that the bus voltage rises excessively, when the motor is actively braked. However the fourth spare phase of the power stage can be fitted with an external resistance and activated for this purpose (this option must be configured during production). For 4 phase motors an external "Chopper module" is optionally available (details on request).

The Control Unit of the SRC4/300-05 is implemented with state-of-the-art, FPGA technology, featuring a powerful Altera Cyclone IV FPGA (with 22,320 logic elements) etc. External sensors are connected through an 8-channel 12-bit A/D converter. Control communication is made through the RS-232 protocol.

Figure 3: Control Unit of the SRC4/5-300

The key features of the board are:

- Altera Cyclone® IV EP4CE22F17C6N FPGA
- On-board 50MHz clock oscillator
- On-board USB-Blaster circuit for programming
- 32MB SDRAM
- 2Kb I²C EEPROM
- 64 MB serial configuration flash device (used to store FPGA and NIOS II boot files)
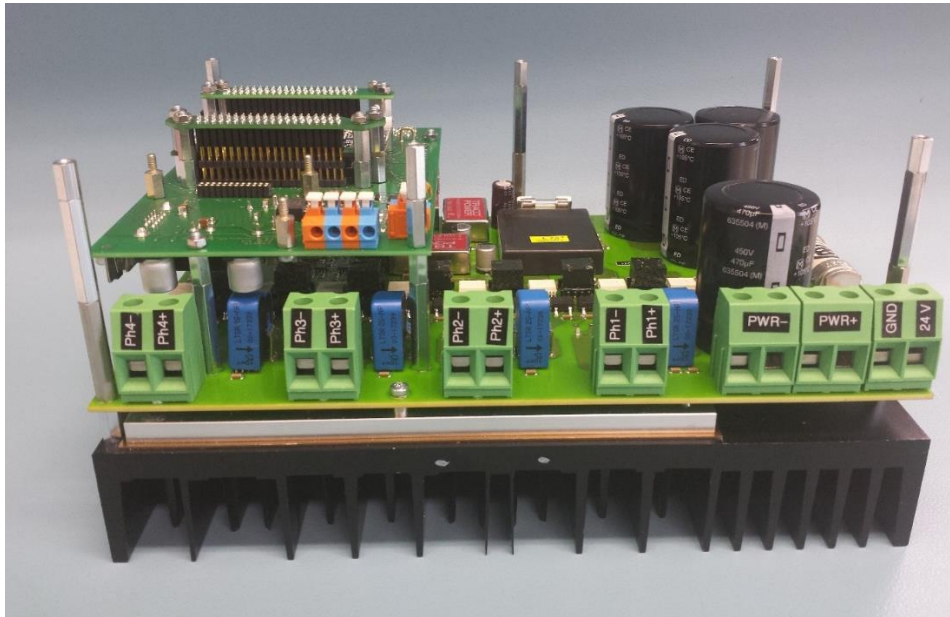
Figure 4: Switched Reluctance Controller – without Housing

Connectors are available on the sides of the SRC.

The Controller has connectors mounted on the power board. In order, to access these connectors, the metal cover needs to be removed carefully (Figure 4). Starting from the right side of the unit, the first two connectors (24V and GND) are for the auxiliary supply. The next two pairs of connectors (PWR+ and PWR-) are the DC Link connections (up to 300 V). The remaining connectors supply the individual motor phase connections (up to 4 phases): Ph1+/-, Ph2+/-, Ph3+/- and Ph4+/-.

In addition there are three control and feedback connectors (Sub-D) mounted on the side and back plates of the controller (Figure 5):

- TTL Encoder interface for position measurement, male D-Sub 9 connector.
- Chopper control and sensor monitoring (current and temperature), female D-Sub 9 connector.
- RS232 port, for PC communication and commissioning, female D-Sub 9 connector.
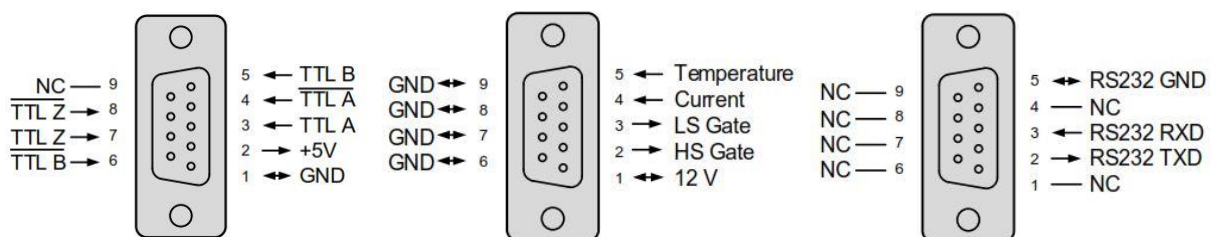
Figure 5: Sub-D Connector Pinning: TTL, Chopper and RS232

SRC-MON, GRAPHICAL USER INTERFACE

The SRC-MON is an intuitive, PC-based GUI to configure and control the SRC4/300-05 Controller. It allows configuration parameters to be set and modified before or during operation. Important variables such as current, speed and position can be monitored during motion. The GUI has two tabs: *Speed/Current Control* and *System Setup*.

On the *Speed/Current Control* tab (Figure 6), the user can change the most important parameters of the system and observe data measured in the SRC. The user can modify parameters like Drive mode, Desired Current, Current limit, desired speed or firing angles.
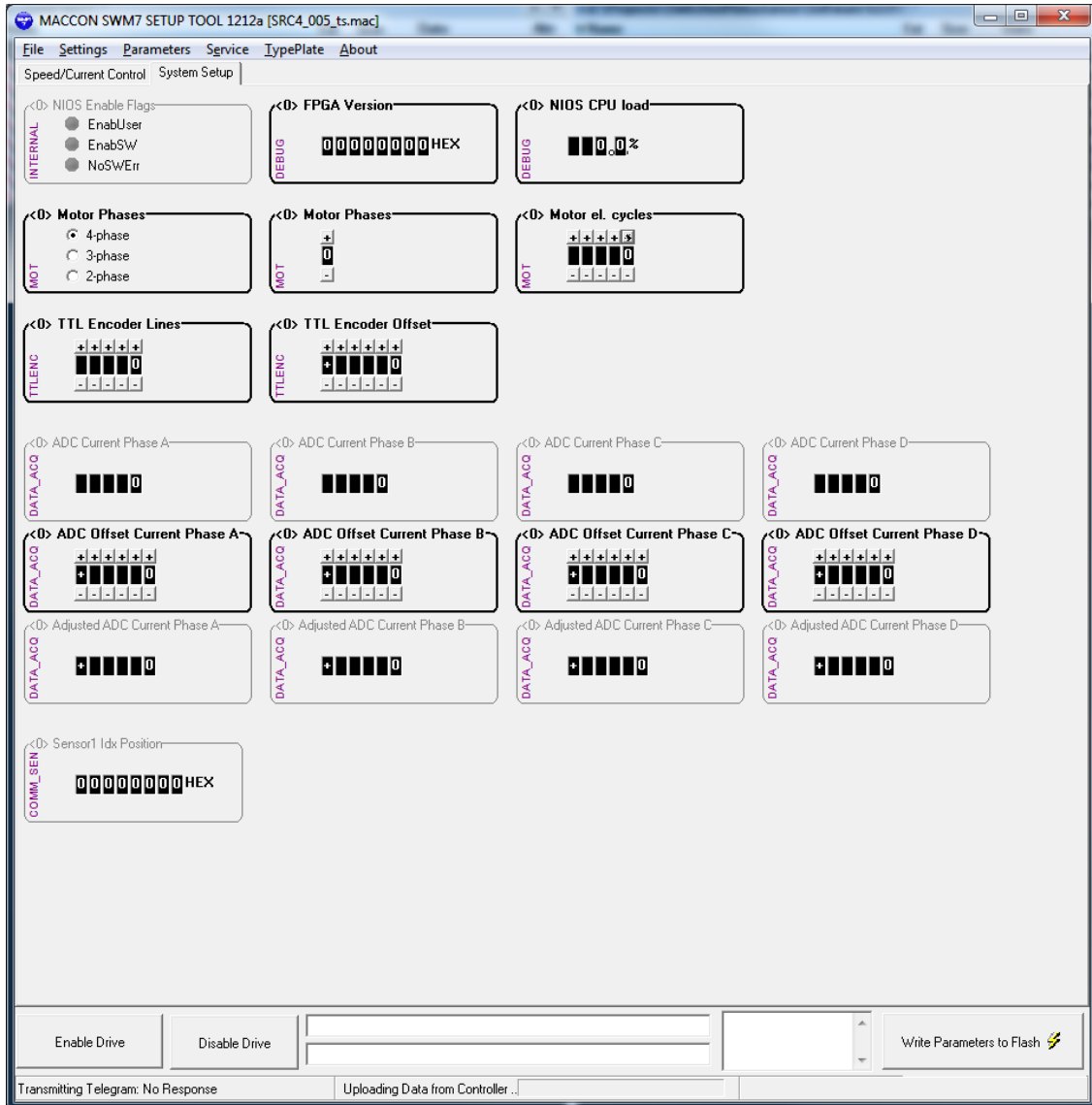
Figure 6: System setup on PC side

On the *System Setup* tab of the SRC-MON (Figure 7), the user can change the system parameters. These parameters are not meant to be changed very often and they are also stored in a volatile memory on the SRC. Once created all the set-up values are loaded from this file when the application is started. Parameters like phase numbers, number of electrical cycles, encoder lines, encoder offset or current sensor offsets can be set on this page.
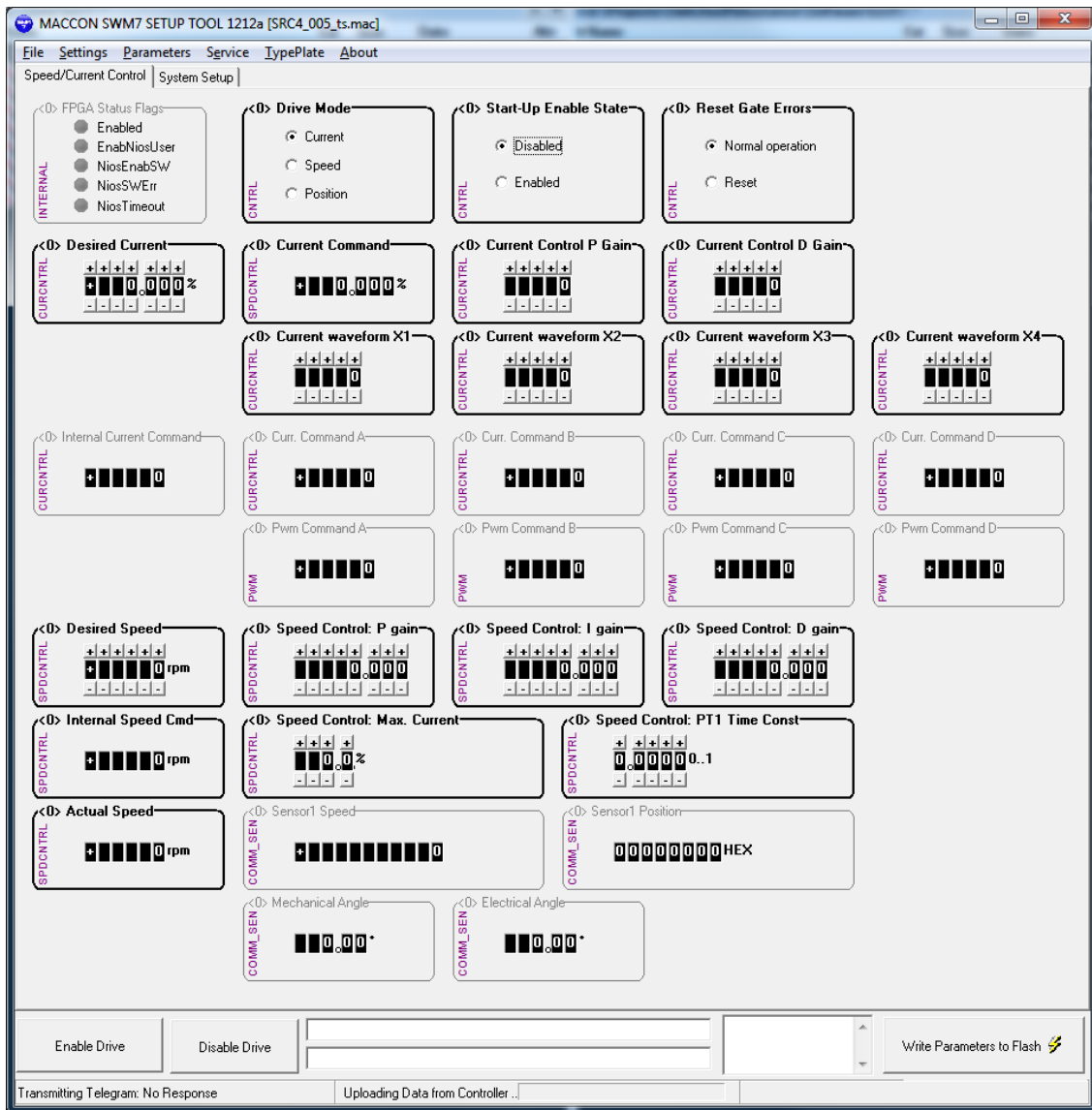
Figure 7: Control of SRC on PC side

These features confer high flexibility during development process of SRMs for wide range of applications, allowing the user to check the parameters defined in the design process on a real system.

INITIALISATION

At power up of the user must turn the shaft of the motor until the reference pulse of the encoder is detected. In the GUI the offset of the encoder is thus set, so that the system knows the absolute position of the rotor.

FUTURE FEATURES

- Firmware update by user
- Position sensor calibration – for initial position detection
- Adjusting of firing angles depending on velocity and load, based on motor simulations (SPEED motor design files)
- Visualization of phase currents, voltage and of motor velocity
- HE-commutation sensor inputs
- Different current forms, in addition to block
- Algorithms and features to customer specification
- Customer configuration of 4th phase as chopper
- Analog command input (over potentiometer)