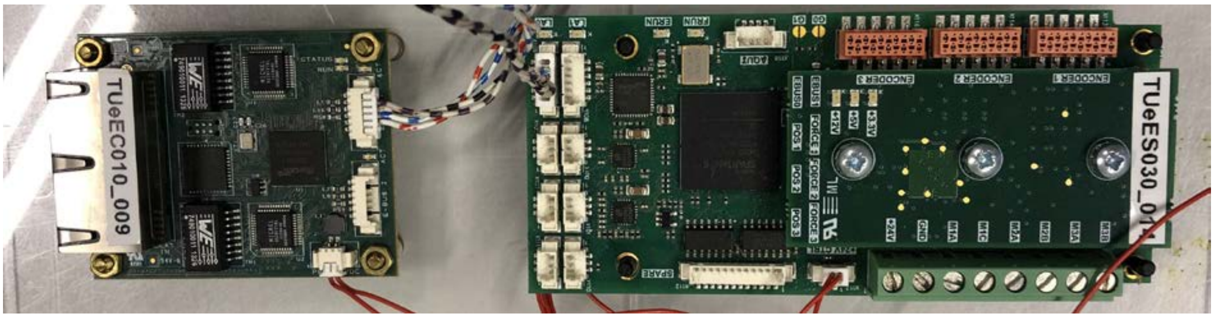


PERA REDESIGN DOCUMENT

Version	Date	Author(s)
0.1	09sep2019	Ruud van den Bogaert, Henk van Rooy
0.2	12sep2019	Ruud, Henk

Introduction

The picture above shows one of the current interface boards that are used in our care robot systems Amigo and Sergio. The left pcb is the EtherCAT interface (ES010) and the right pcb is the multifunctional measurement and control board (ES030).

Both boards are also applied in experimental setups used for research purposes in the labs.

Past experiences, current developments and questions of potential users give us the need for a new (re)design of these interface boards. Most of the functionality has to remain (maybe even expanded), this is also the case for the mechanical footprint of the hardware

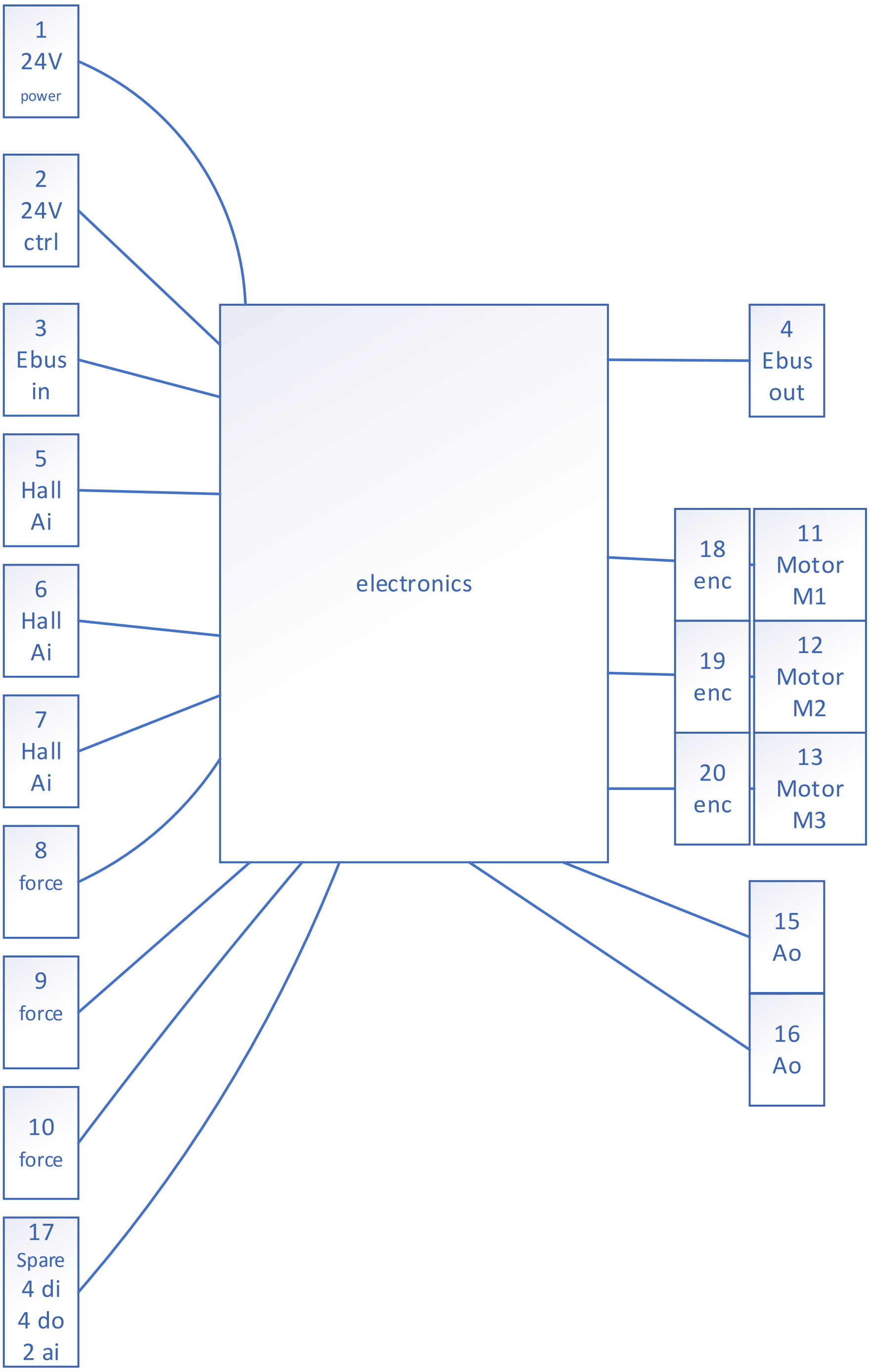
Functional diagram

The most recent control board (ES030) has the functionality of the block diagram in Figure 1. This will be explained later on in this document.

Motivation for the redesign

The following points make the redesign desirable:

1. The FPGA is VHDL based, which is complicated to manage and maintain if local experience is limited. Additional functionality is not easy to implement.
2. The Altium toolchain used for the development discontinued embedded FPGA support in 2016.
3. The resulting niche programming environment with Altium blocks combined with VHDL and C is not future proof.
4. Converting it to a Xilinx environment is complicated and does not resolve the first item.
5. The applied AD1543 A/D converter is obsolete and must be replaced
6. The applied Beckhoff ET1200 ASIC is not recommended for new projects. The ET1100 may be more suitable, although a little bigger in dimensions.
7. The new design should also be able to be used as an all-round experimental EtherCAT control setup in the robotics lab facility.
8. Being able to use Simulink for programming the resulting design is a strong preference.



1 Basic functional diagram of the control board

Requirements, preferences and constraints

From the initial design considerations of the year 2013 and beyond, as described in paragraphs about the current hardware (after this paragraph), the following RPC's can be distilled for the new design:

Table 1 - Requirements, Preferences and Constraints

R1	3 Encoder inputs, A, A/, B, B/, I, I/. Approx. 78 KHz, differential line receivers, 10 pole Micro-Match connector.
R2	6 Analog inputs, 0...3,3V, (AS1543-BQFT), A/D 12bit resolution, Molex PICOBLADE 53047-0310.
R3	2 Analog outputs, (AD 5722R) D/A 12 bit, Molex PICOBLADE 53047-0210.
R4	3 Motor drivers, H-bridges, 3A, Phoenix Contact MKDSN 1.5/8-5.08, 3 motors and 24V input.
R5	2 EtherCAT I/O ports (or EBUS link, Molex PicoBlade. Molex PICOBLADE 53047-0610).
R6	1 Spare IO: 4 digital outputs (5V), 4 digital inputs (5V) and 2 analogue inputs (12 bits, 0-3V3), Molex PICOBLADE 53047-1210.
R7	3 Current measurement, sampling freq. 20 KHz, circular buffer for 100 samples, resolution 12 bit.
R8	Same form factor as the TUE ES 030 and TUE ES 010 (Possible replacement for existing boards in our robots).
R9	ARM processor based.
R10	Directly programmable in Simulink. Block-set and sources are part of the deliverables.
R11	Robustness (polarity, overvoltage and short circuit protection).
P1	Translate existing FPGA functionality to Simulink. ->> is it doable??
P2	Casing for the stand-alone version.
P3	Connectors at the same location as the current design
P4	Analog I/O level switching to ±10V, 12 bit.
C1	Mechanical dimensions for control board as mentioned in 'Mechanical Specification'.

Description of the current hardware

The current hardware was designed from 2013 on. This paragraph shows the design considerations that led to the current hardware.

As mentioned, the current setup comprises two pcbs:

1. The TUE_ES010, which is 2 channel EtherCAT coupler based on the Beckhoff ET1200. No special problems here. Functionality remains as is.
2. The TUE_ES030 (and the TUE_ES020). The ES030 version is an extended version of the ES020. This will be explained later.

TUE_ES_020 specs technical specification 2013 (Amigo)

(The numbers after each entry refer to the numbered labels in the functional diagram).

Power supply: (1) The supply of the motor driver module will be 24V+/-10%, rated at approx. 12A per PCB. The module derives its internal voltages from this supply. The power supply is connected through a PTR AK500 type connector.

Logic power supply: (2) Processor power supply 24V+/-10%. If the motors are powerless or the emergency break was activated the encoder information must still be available. This supply is connected to a 2-pole PicoBlade connector.

Brake resistor: No brake resistor is included in the design since there is no space on the PCB's. External measures (optional external brake resistor or capacitors) should prevent the supply voltage to rise to excessive voltage levels due to braking actions of the motors.

Filtering: Due to the high currents and the restricted available board space, the filtering measures on the PCB's are limited. External filtering measures might be necessary if the PCBA's have to pass EMC tests for CE certification.

12V power supply: The 12V supply is powered from the 24V supply and used for the control electronics of the H-bridges.

5V power supply: This supply is a DC/DC converter rated at approx. 0.5A and is used for powering the external sensors and the 3V3 supply. The current for the externals sensors is limited to 100mA max

1.2V and 2.5Vpower supply: These supplies are used for powering the FPGA and are derived from the 5V supply.

3.3V reference supply: This is the reference voltage generation for the ADC's

FPGA: The selected XC6SLX25-3FTG256C is used for handling the motor driver signals, sensor signals, and communication and encoder signals. A FPGA is selected for correct encoder signal handling which includes pulse counting at relatively high frequencies.

Encoder inputs: (18, 19, 20) There are 3 encoder inputs, each consisting of differential A, B and Index signals at speeds up to approx. 78 kHz per signal. The encoder inputs are equipped with differential line receivers and 10 pole Micro-Match connectors to ensure compatibility with the current encoders. The Micro-Match connectors also contain a motor connection for low power motors (up to approx. 0.5A) which is derived from H-bridge 1, 2 or 3.

H-bridge: (11, 12, 13) There are 3 H-bridges, built around 2 pcs DRV8412 from Texas Instruments. One DRV8412 is operated in parallel mode and capable of delivering a maximum current of approx. 6A continuously* to motor M1. The other DRV8412 is operated in dual mode and capable of delivering a maximum current of approx. 3A continuously* to motor M2 and M3. Optional, it is possible to operate M2 and M3 in parallel mode by means of a (solder) jumper or external wires. The motors are connected through PTR AK500 type connectors.

*these maximum currents depend on the heat transfer from the integrated circuits to the housing and the surrounding air. Measures will be taken to optimize the heat transfer by means of thermal conductive materials.

Mounting of the H-bridge: the H-bridge IC's will be mounted on the bottom of the PCB's. Large ground planes will facilitate a good thermal connection to the PCB. As a secondary cooling measure, thermal conductive material will provide thermal contact between the H-bridge housings and the underlying metal robot frame.

Sensor inputs: (5.. 10) Up to 6 analog sensors can be attached to the motor driver controller. The sensor connectors accept an analog input voltage of 0...3.3V with a 12 bits resolution using an ADS1543. Sensor power (5V) is provided on the sensor connector. The sensor connector is of the type Molex 53047-0310 (same connector as current sensor connector).

EBUS: (3, 4) EtherCAT communication is present as an interface to the module by means of an ET1200 preprogrammed device. The physical layer of this communication is EBUS (LVDS). The motor driver controller has 2 EBUS ports, each connected via a separate 6 pole JST ZR-SM4 connector.

2 channel DAC, 12 bit: (15, 16) Connected to a Molex PICOBLADE 53047-0210.

Spare IO: (17) 4 digital outputs (5V), 4 digital inputs (5V) and 2 analogue inputs (12 bits,0-3V3) are present for future expansion, sensors etc. These outputs and inputs are not protected due to board space limitation.

Cables: cables and mechanical parts are not included in this quotation.

Sensors: no sensor PCB's will be created during this design. The current sensor PCB's can be connected to the driver board prototypes.

Mechanical Specification (must be checked!!)

The module consists of a single PCB of approximately 110*50mm. Mounting holes will be foreseen as on the original PERA driver boards, and 2 indents of 2.5*8mm will be created to ensure a correct fit on the mechanics. Height is limited to 12mm from the standoffs (PCB + components), up to 4mm depth is required below the PCB for proper mounting of the H-bridge drivers.

The voltage regulators will be mounted on a piggy back PCB because the space on the main PCB is not sufficient. This piggy back PCB will be mounted upside down above the FPGA and remain within the allowed outer dimensions.

Update to TUE_ES_030 2014 (Sergio)

1. Change current-measurement
2. Change PROM by SPI flash
3. Add a 2 channel DAC + connector and some minor changes, like:
    a. Change polarity X117
    b. Change 10M resistors in 8M2

Relevant documents

Further information can be found in the following documents:

Alex Andriën, Ruud van den Bogaert, *TUeES03 Manual*, report CST 2016.141, Eindhoven University of Technology, section CST, May 2016

Alex Andriën, *TUeES030 Quick Start Manual*, Eindhoven University of Technology, section CST, April 2016

Database pcbs: TUeEterCAT