INAF – OSSERVATORIO ASTROFISICO DI ARCETRI

VRALA ELECTRONICS

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VRALA electronics has been conceived as a development system capable to measure the displacement while driving the actuator coils. Since the displacement causes a change in the value of the coil inductance the main task of the electronics becomes to drive both the coils while performing their inductance measurement. With VRALA electronics the coils work as, at the same time, actuators and position sensors. This feature can improve the overall ratio between force and power consumption in the adaptive optics mirrors. The displacement capacitive sensors are no more necessary, so the heat dissipated in the secondary mirror is reduced to the pure necessary level to obtain the displacements. Since the next generation deformable mirrors will feature one thousand, or more, actuators, the total power consumption will have a relevant role. VRALA electronics drives the coils using high efficiency switching technology, a key feature to reduce power consumption at drivers level. Such a technology, in the next step of development, will lead to an high efficiency electronic control system for the new generation deformable mirrors. Moreover, leveraging commercial devices developed for switching DC/DC converter, the total cost and the dimension of a prototype will be reduced as well.

Theoretical background

The relationship between the time-varying voltage v(t) across an inductor with inductance L and the time-varying current i(t) passing through it is described by the following differential equation:

$$V(t) = - L \frac{di}{dt}.$$

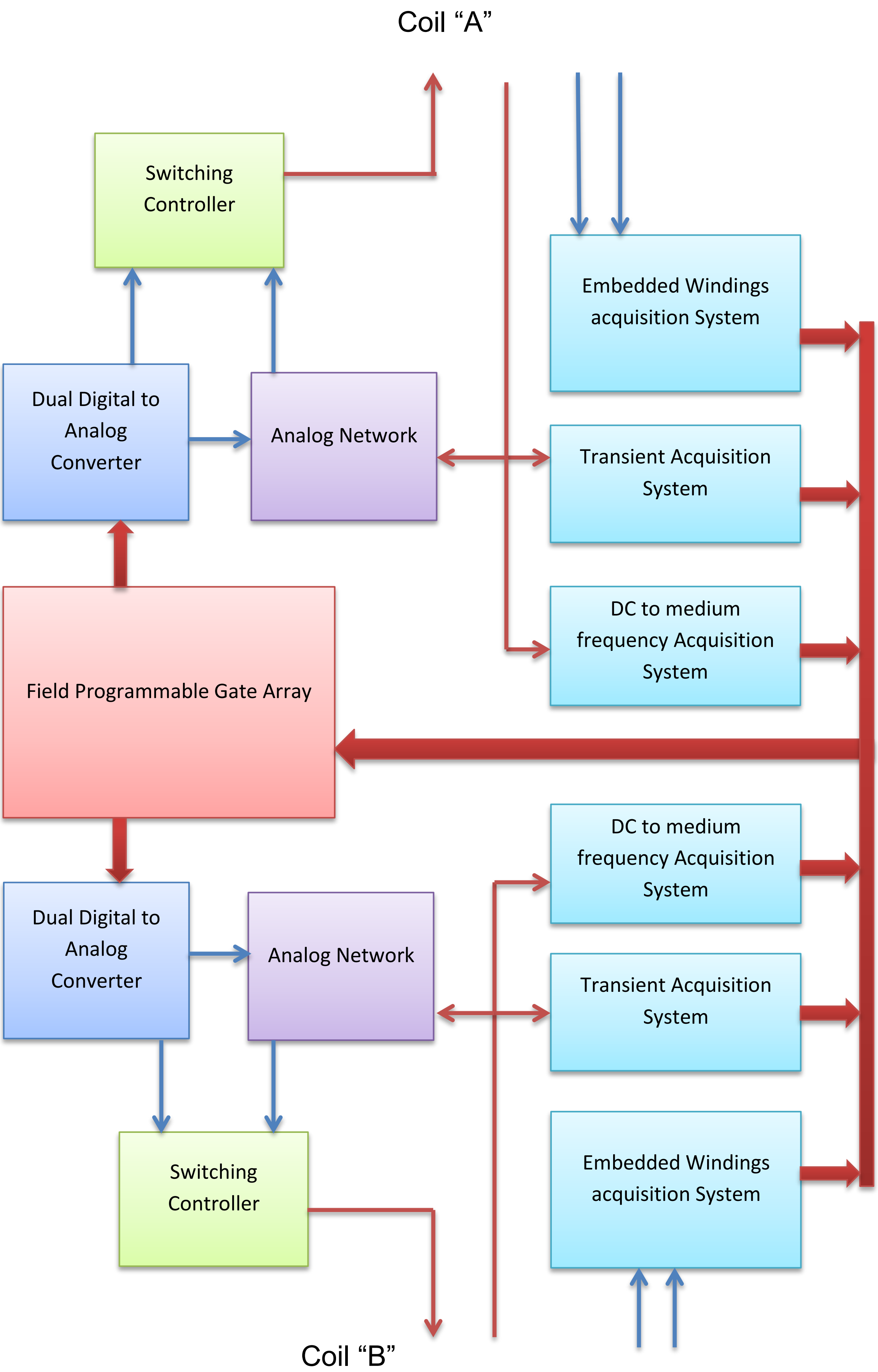
Moreover, the relationship between the time varying magnetic flux φ(t) and the voltage induced V(t) is described by the Faraday's law:

$$V(t) = - \frac{d\varphi}{dt}$$

Assuming that the moving part between the two coils will change the magnetic flux and the inductor values, we set up two measurement strategies. The first is due to an embedded winding which acts as a "variable transformer", the second is to measure the current during voltage transient and at low frequency, in the bandwidth of the control loop.

VRALA electronics contains three acquisition systems for each coil. One of them is devoted to acquire the voltage generated by the embedded winding via magnetic coupling, one is optimized to capture current transients, and the last is tailored to sample the current signal in the bandwidth of the control loop. Each acquisition system was built using a fast, low noise differential analog-to-digital converter, with a sampling rate of 16 Bits at 4MHz. A differential low noise and low distortion amplifier provides a balanced signal to the converter. A Field Programmable Gate Array FPGA generates all the timing signals and performs all the necessary functions to close the position control loop.

Block Diagram



VRALA electronics has a Field Programmable Gate Array which controls and supervises all the devices on the board, except the analog network. The actuator is made up by two coils, named coil "A" and coil "B", consequently the electronics has two identical parts for the data acquisition and the generation of the driving signals. Each part performs three acquisition strategies to measure the inductor value, there are three analog to digital converters connected to amplifiers with gain and bandwidth calibrated to acquire the coil current in the low frequency band, in the high frequency band and the magnetic flux variation, via the embedded windings. The FPGA collects the data and calculates the actuator position using a look-up table stored in the internal memory. The difference between the required position and the actual position is digitally filtered, using an Infinite Impulse Response Filter. The resulting data are converted to an analog signal applied to the Switching Controller. This describes the digital way to close the position control loop. The VRALA electronic board includes also an analog network able to perform the pole zero compensation for the position control loop. This is the analog manner to perform the position control loop. As a consequence, both strategies can be implemented on the same electronic board, so that the choice for the prototype version can be easily made. The VRALA schematic diagram is organized in a hierarchical way, the root schematic is VRALA TEST BOARD (fig.1). This schematic describes the programmable device, the configuration device and the connections between them and other blocks. Blocks with green border represent schematic diagrams at lower level in the hierarchy. They include COIL "A" and COIL "B" schematic diagram, the power supply and a digital interface schematic diagram.

Fig. 1 – VRALA TEST BOAD schematic

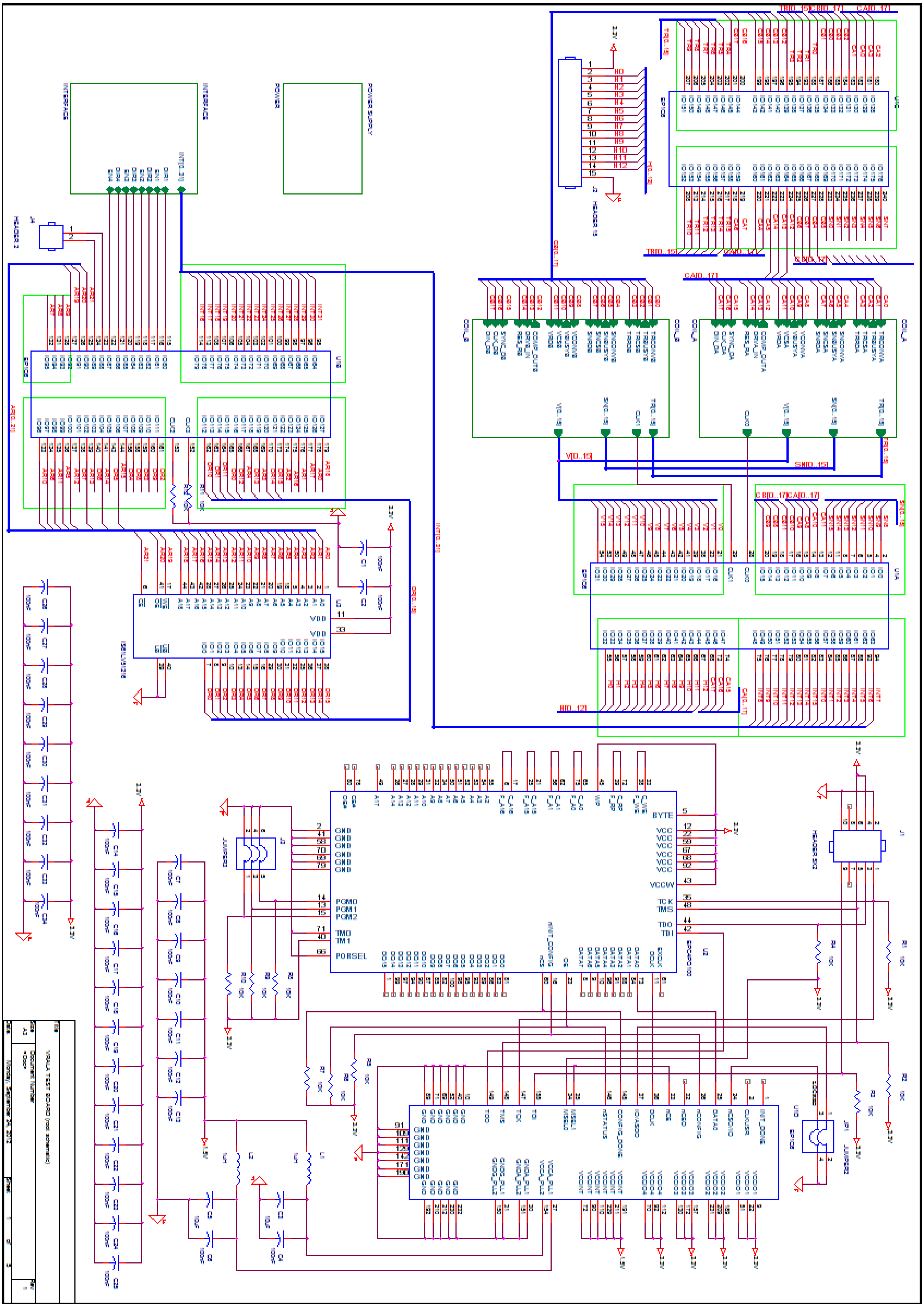


Fig. 2 – COIL A DRIVER schematic

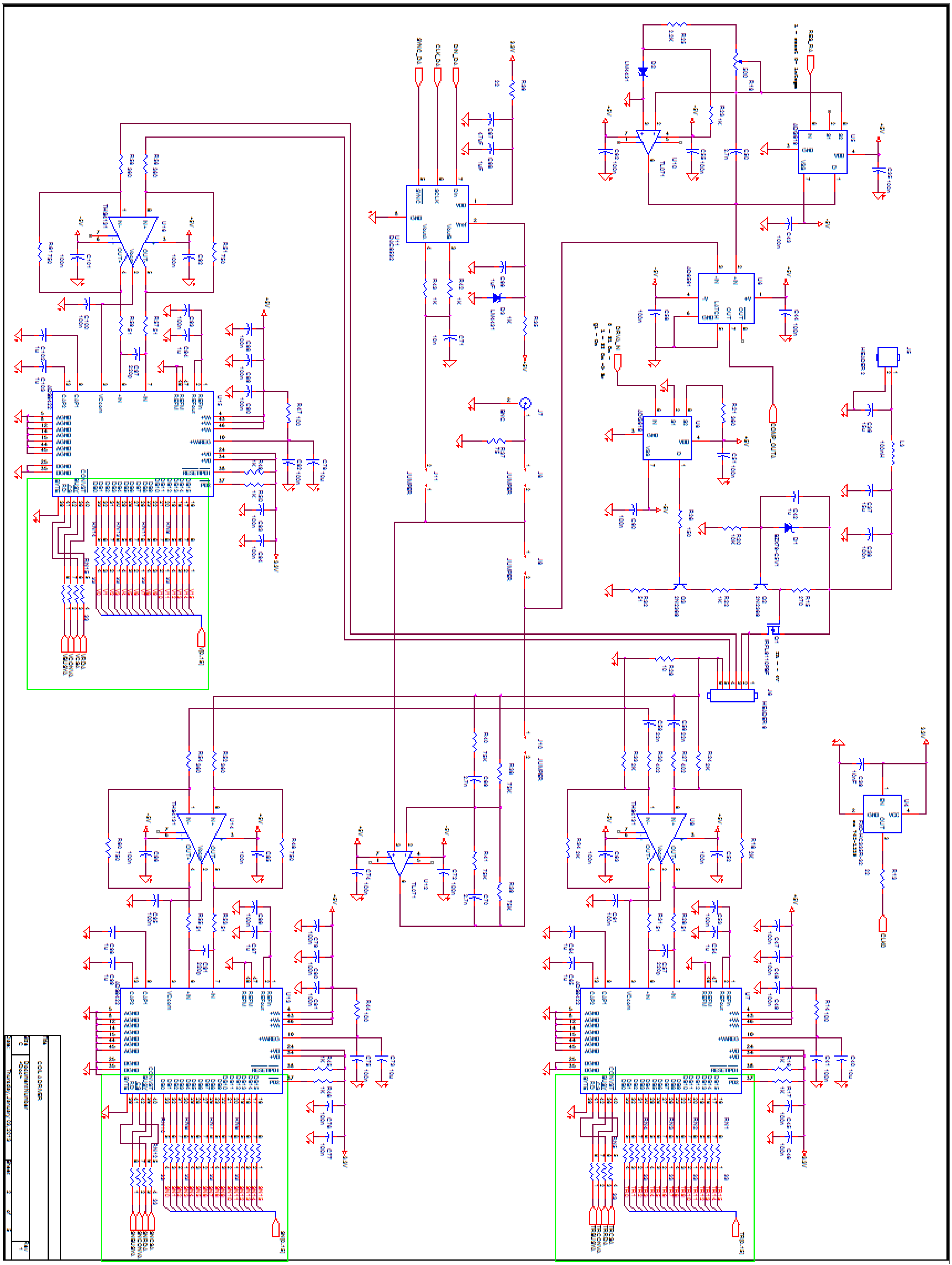


Fig. 3 – COIL B DRIVER schematic

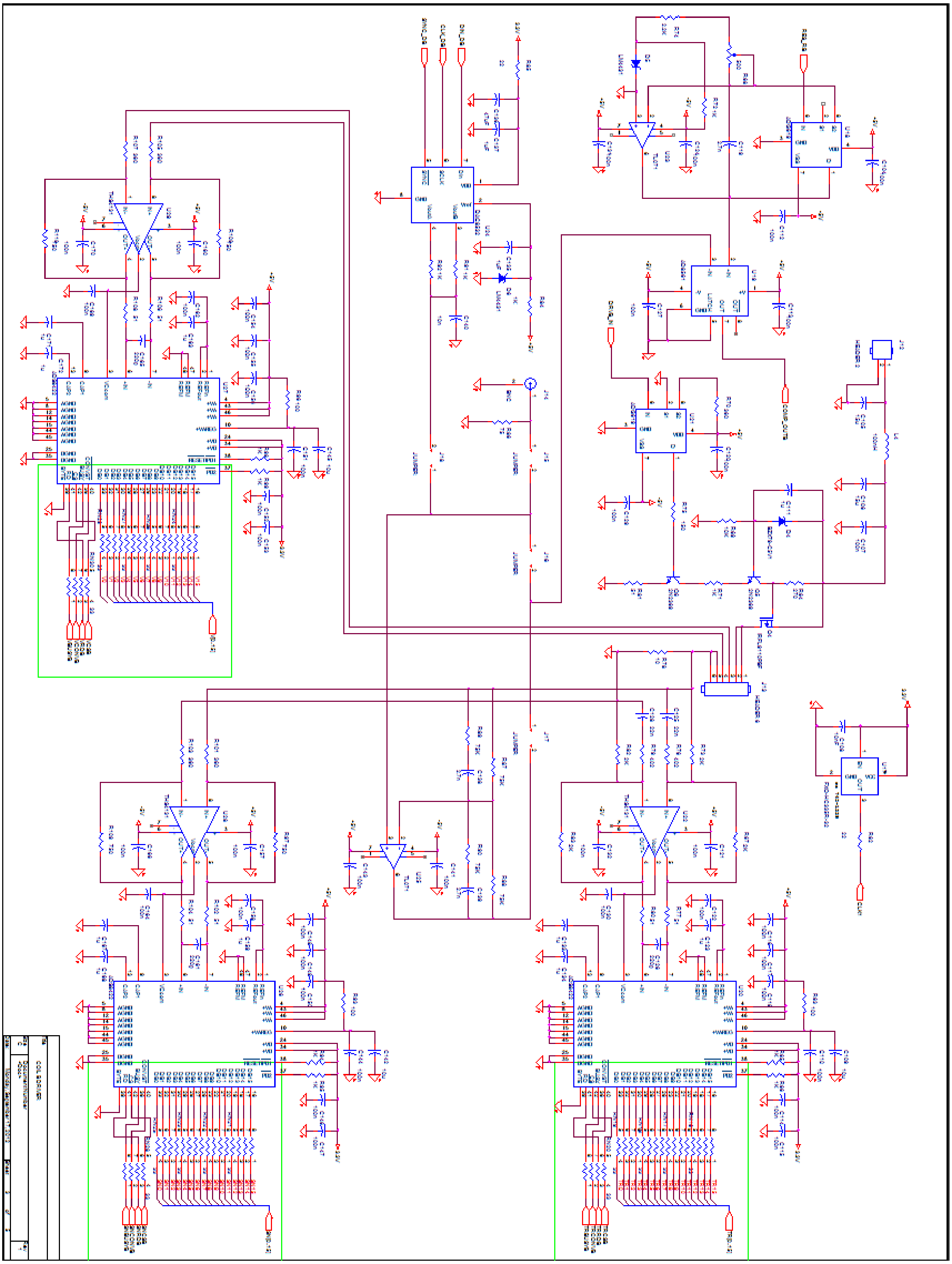


Fig. 4 – VRALA INTERFACE schematic

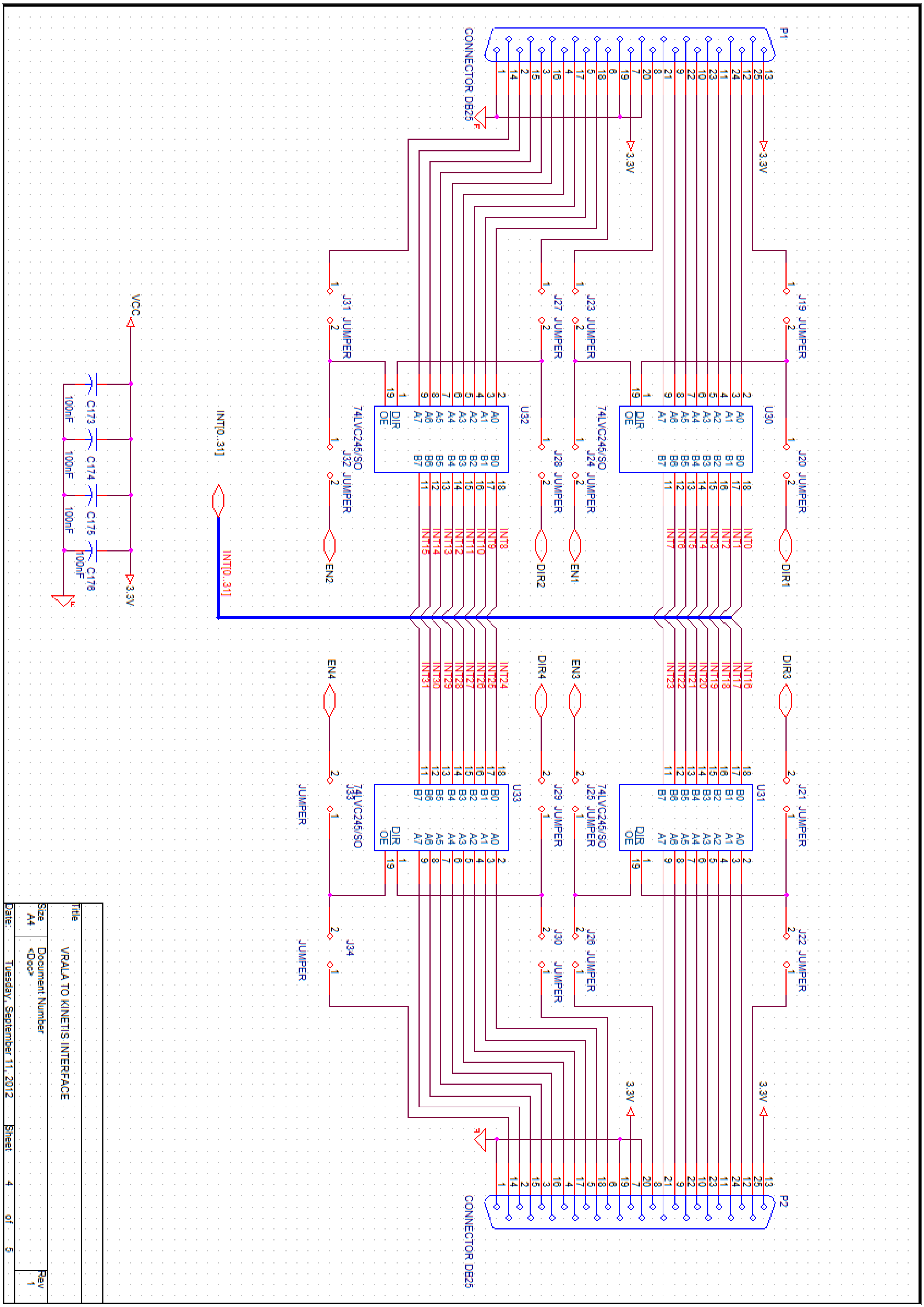


Fig. 5 – VRALA POWER SUPPLY schematic

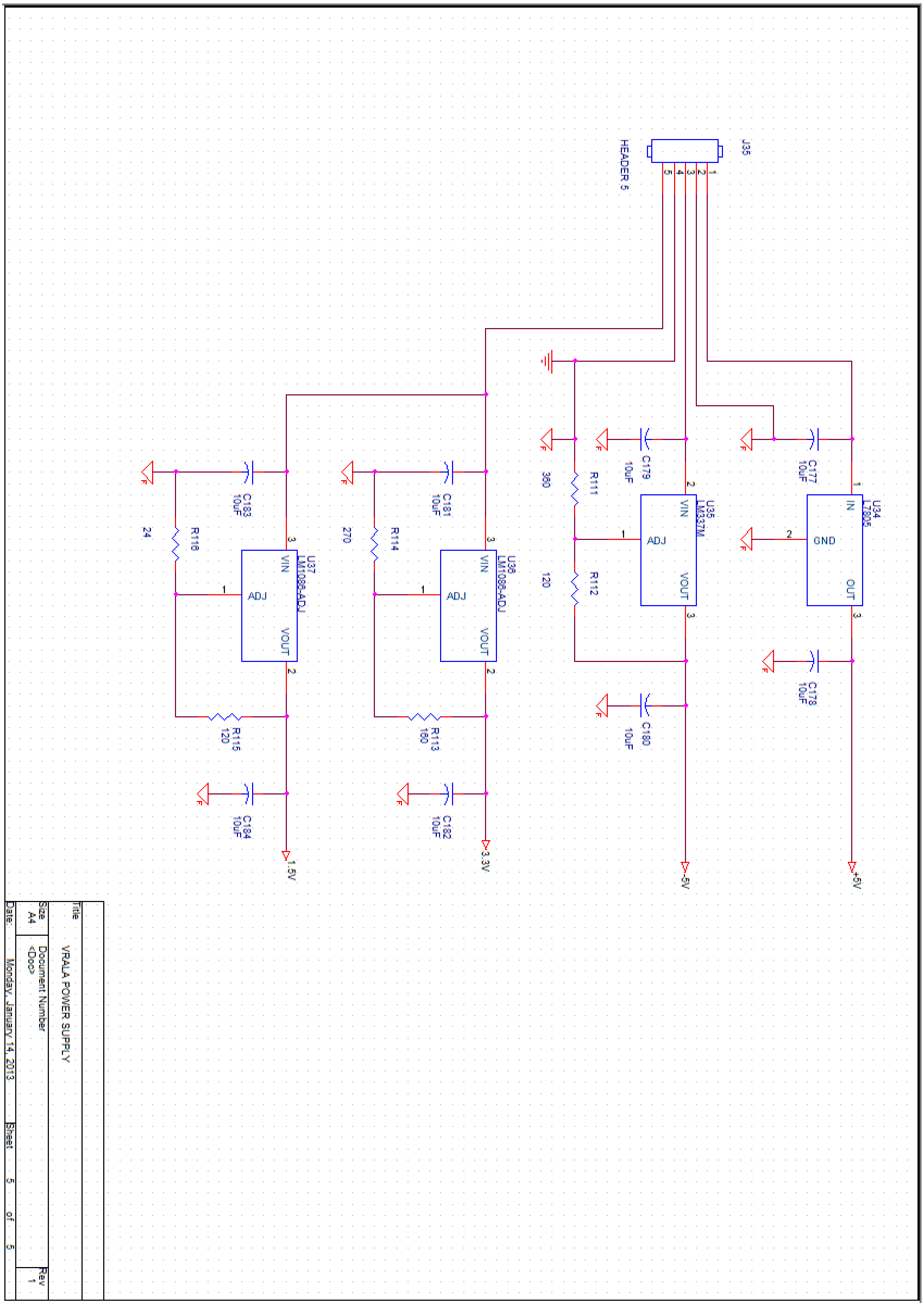


Fig. 6 – VRALA BOARD.

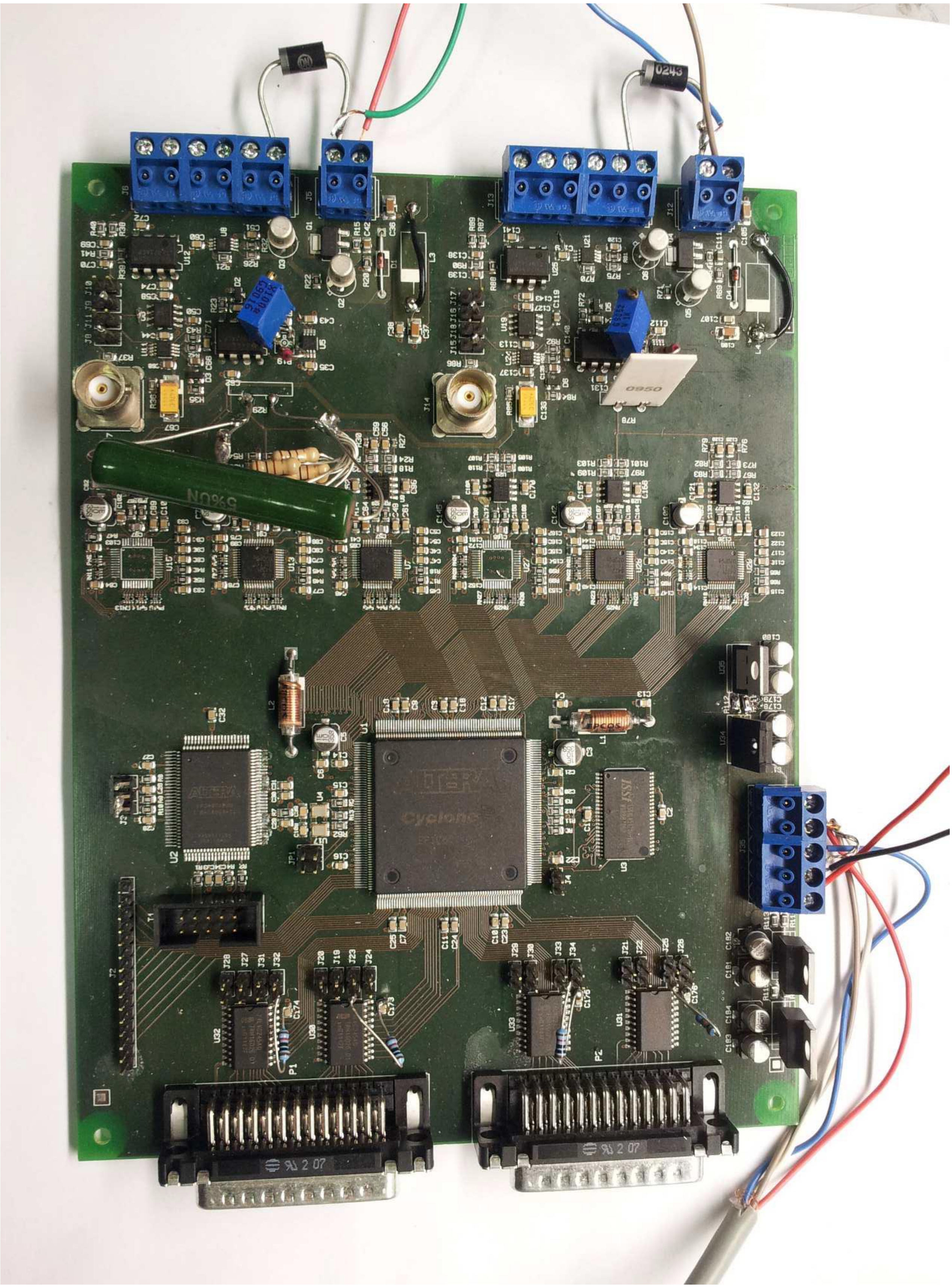
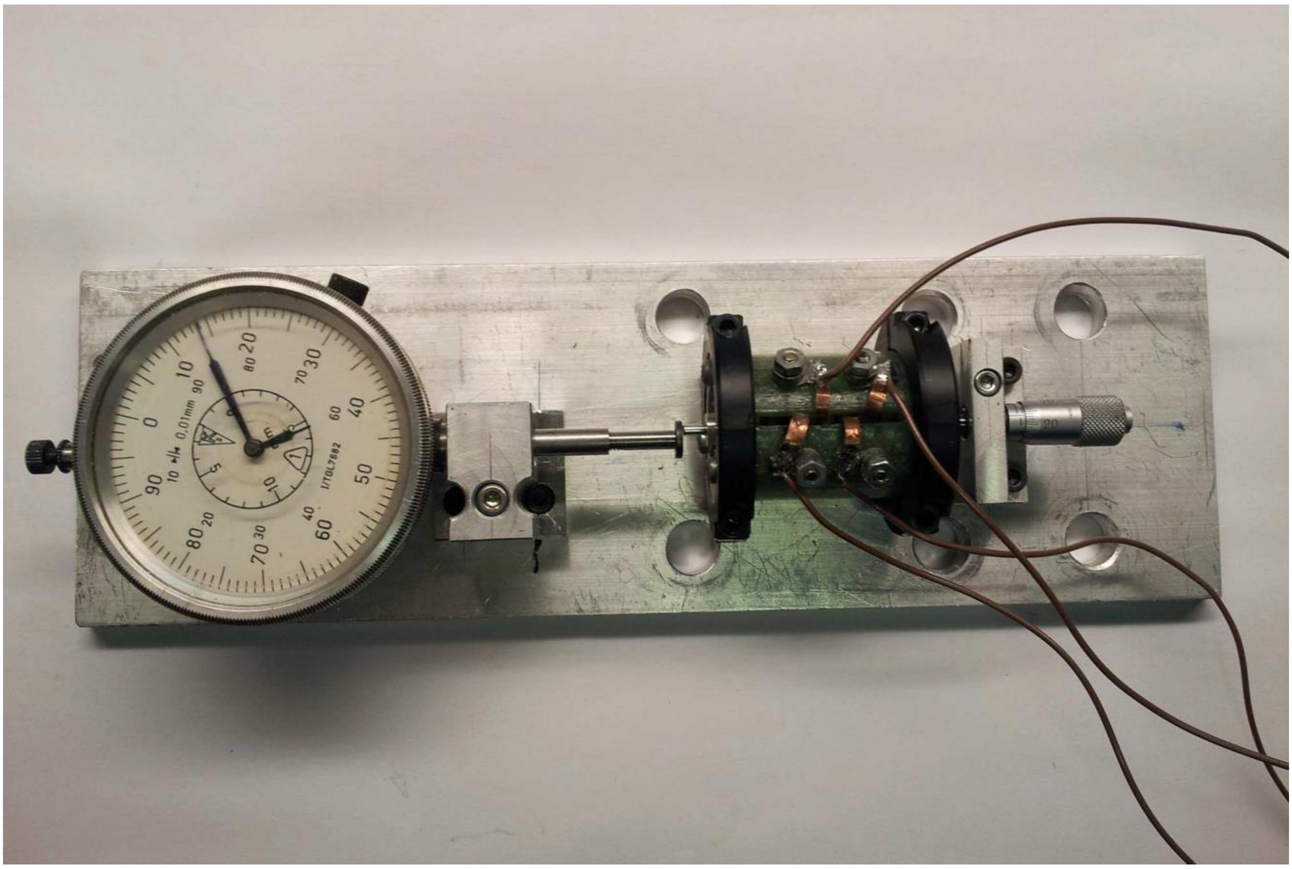


Fig. 7 – The prototype.



TEST RESULTS

Some preliminary tests on the supplied prototype with VRALA electronics did not give the expected results. Further investigations showed that the inductance value changed when moving the mover only for frequencies less than 30KHz. This behavior is a potential issue, as the control loop bandwidth could collide with the frequency to run the inductance measurement. Moreover, due to this limitation, the measure frequency must be less than 30KHz. As a result, the time interval at which the measure is acquired must be greater than 33µs, which acts as a 0-order delay in the position control loop. This is a severe limitation for the control loop bandwidth, which would require to work as fast as possible – typically at <1µs – in order to obtain the highest bandwidth as well as the lowest settling time. In fact, the analog to digital converters are able to sample up to 4MHz.

The cause of this unexpected behavior is probably the strong μ_r decay of the soft magnetic material when increasing the frequency. We are currently investigating with the material supplier about more accurate tests; meanwhile, we are also inquiring about alternative materials, featuring not only magnetic performances and a very low conductivity, but also a constant μ_r up to 1MHz.