Constant current power supply for powering deflection and focus coils

1. Introduction

Beam deflection power supplies are often required around accelerator beam lines to 'trim' the direction of an accelerated particle beam or to shape is (e.g. using quadrupole focusing elements, as shown in Figure 1). Such power supplies often need to deliver relatively low currents and operate at low voltages. Of course such supplies can be purchased from numerous specialist suppliers, but when you need lots of them, it I often more cost-effective to make your own, particularly when output powers of the order of a few watts are only required. We describe here a versatile Eurocard-sized board which we use in the Institute's electron linear accelerator. The circuit board is versatile in the sense that unipolar positive, unipolar negative and bipolar outputs can be obtained, providing currents of the order of 1A or more, in response to a unipolar 0-4V signal derived from digital-to-analogue converters.

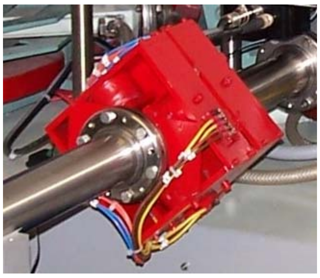

Figure 1. One of the quadrupole focus coil assemblies used in our linear accelerator

These boards have been found to be versatile and easily adaptable for driving steering and focusing coils, and used readily available components. A printed circuit board layout is presented and very simple machining of the built-in heatsink is required.

2. The constant current power supply

Inductive loads are best driven from constant current sources and a simple way to achieve a voltage-controlled constant current drive is shown in Figure 2. The output current, i_{out} flows through the floating output load and has a value determined by the input voltage V_{in}, such that $i_{out} = V_{in}/4$, with the component values shown. Once set by the input voltage, this current is maintained, irrespective of the load resistance, until the load resistance increases to the point at which the output current cannot be maintained by the supply voltage Vs (or –Vs). The minor disadvantage of this arrangement is that the load must be floating; this can be easily achieved when driving loads such as deflector coils etc.

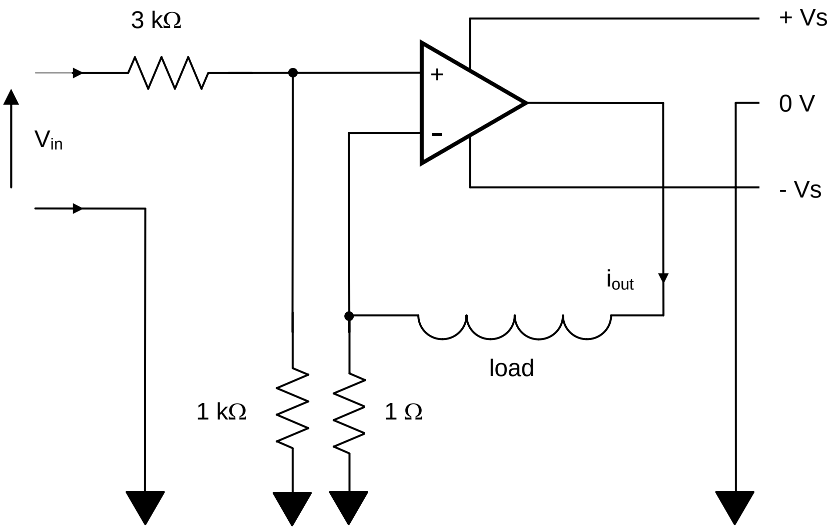

Figure 2. Principle of the constant current source, delivering a current through the inductive load, proportional to the input voltage.

The circuit can deliver bipolar output currents, as determined by the polarity of the input voltage. As shown in Figure 3, this input voltage is derived from a differential amplifier, A1 or C1, arranged such that it can operate as a buffer or inverter, with or without a DC offset, depending on the links inserted at A1's (or C1's) input. The output current can be monitored by sensing the voltage across the 1 Ω current sensing resistor, appropriately amplified by opamps A2 and C2.

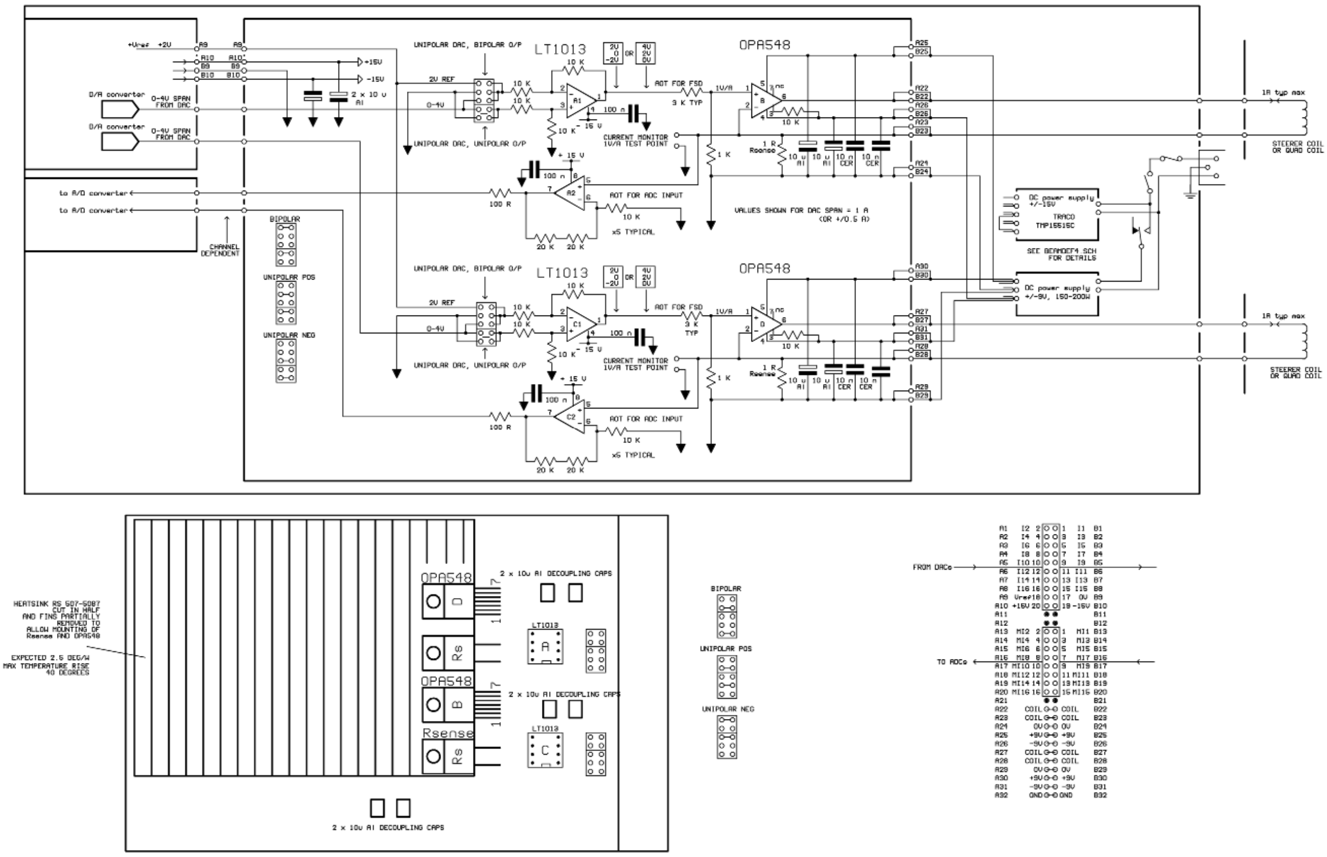

Figure 3. Circuit diagram of the constant current power supply board, arranged to house two identical circuits.

We use OPA548 power amplifiers (http://www.ti.com/product/opa548) to implement the current sources. These are conveniently available in 7-lead TO-220 packages.The maximum output current is 3A, set by the 10 kΩ resistor on pin 3 of the device.

We note that when driving highly inductive loads, some form of back-emf protection is advised. We took the view that it would be more convenient to place such a protection circuit off the board, i.e. across the load itself. In this way a more generic board can be constructed an duplicated, since the protection components could be somewhat bulky and are best placed near the load itself. When air-cored (e.g. steerer) coils are used, no protection has been found to be required. Higher inductance loads can be protected with two back-back zener diodes, capable of supporting the reverse currents generated by switching currents in the load inductance.

3. Construction

Two identical circuits are constructed on a single 160 x 100 mm printed circuit board. The current sense resistors are mounted on the same heatsink as the power amplifiers. We use resistors made by Vishay (part #LTO030F1R000JTE3, available as RS part #532-8173. The layout on the double-sided printed circuit board is straightforward. We not that the input and the current monitor points are not brought out to specific pins on the Eurocard, but rather each can be linked to one of several pins: this allows us to use a ‘flat’ IDC-type cable to link several such boards in a chassis, allowing a single multi-DAC and multi-ADC board to control all the devices.

Each dual current output board uses one half of a 1.1 degC/W heatsink, RS 507-5087, Aavid Thermalloy type OK278/B/75, 200x75x25 mm fin height. We cut this in two and machine down some of the fins, to allow mounting of the power devices. We estimate that the thermal resistance of

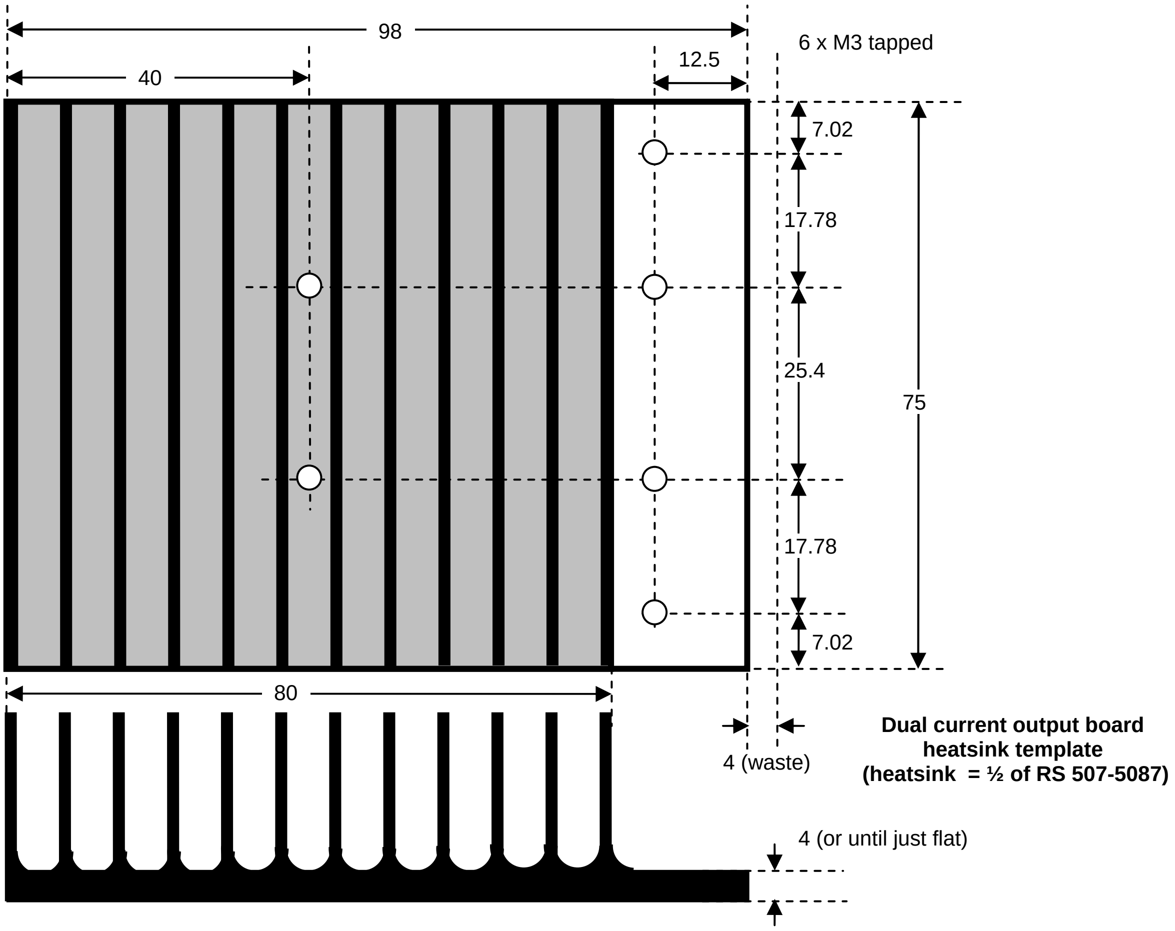

Figure 4. Dimensions of the ‘cut-down’ heatsink used in the constant current power supply board

such a cut-down heatsink to be of the order of 2.5 degC/W. Of course the ‘other’ half is used in the construction of another board. The heatsink dimensions are shown in Figure 4

Board layouts are available on request (Number One Systems EasyPC (version 14 or below, http://www.numberone.com/) but are shown in Figure 5a and 5b for completeness. We use PCB-Pool for board manufacture (http://www.pcb-pool.com/ppuk/info.html) and board assembly is straightforward.

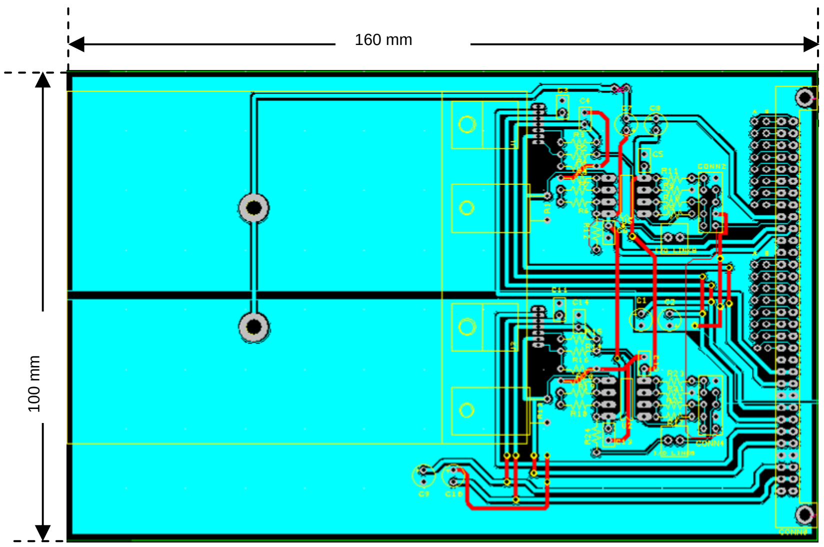

Figure 5a: The dual-sided printed circuit board layout of the constant current driver

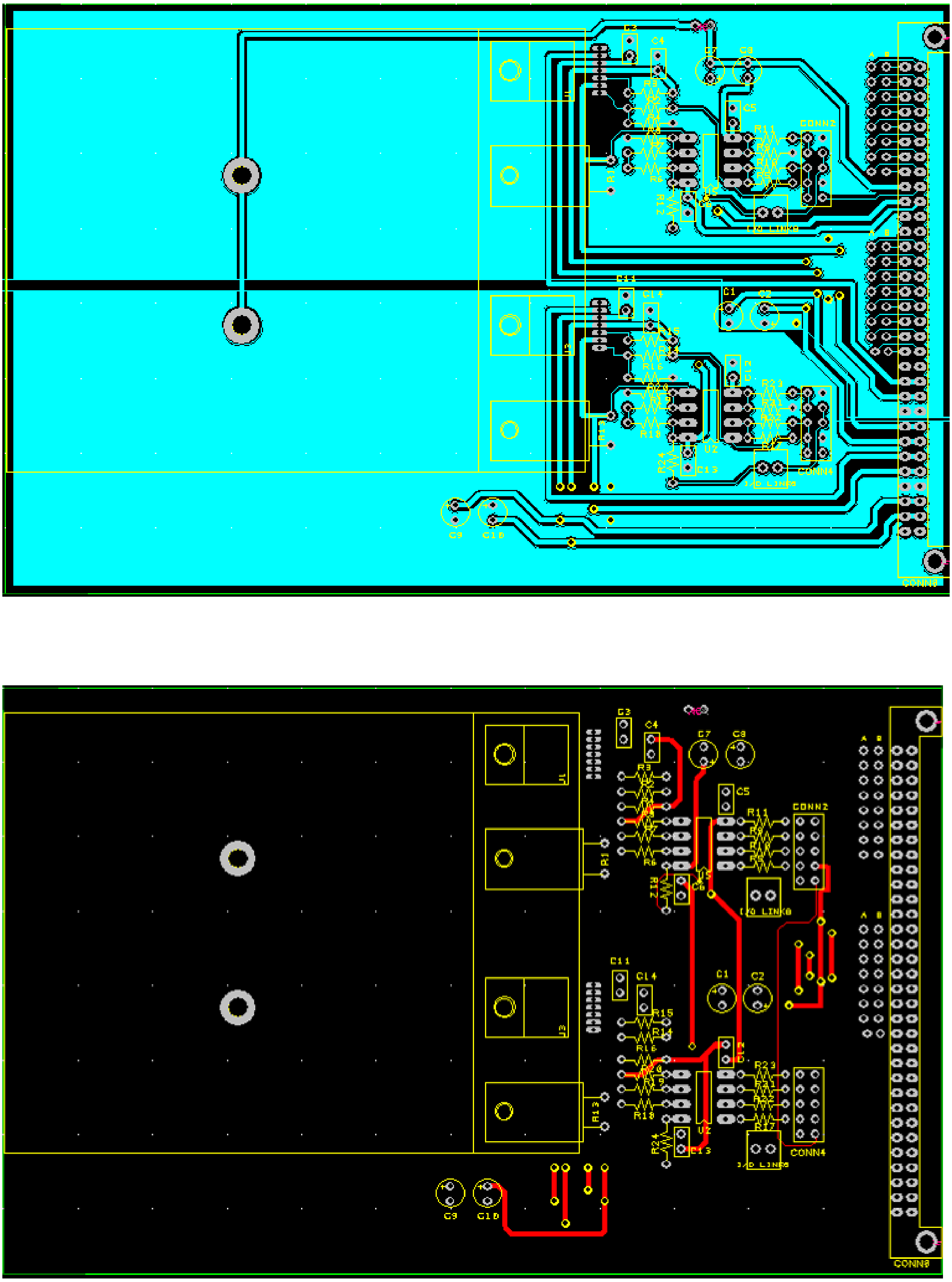

Figure 5b. The two layers of the double-sided board used in the constant current driver shown in Figure 3.

The completed board is shown in Figure 6. Its performance is boringly great – i.e it does exactly what it is meant to do! In our linear accelerator system we use several such dual supply boards and of course total power dissipation must be borne in mind when several units are used in the same enclosure. Reducing +Vs/-Vs is always desirable, and these supplies should be chosen to suit the loads; in our case, most of the coils had resistances of the order of 5-10 Ω, so a raw dc supply of ~±9V was used.

Forced air cooling is of course always desirable, even if this does result in headaches due to fan noise!

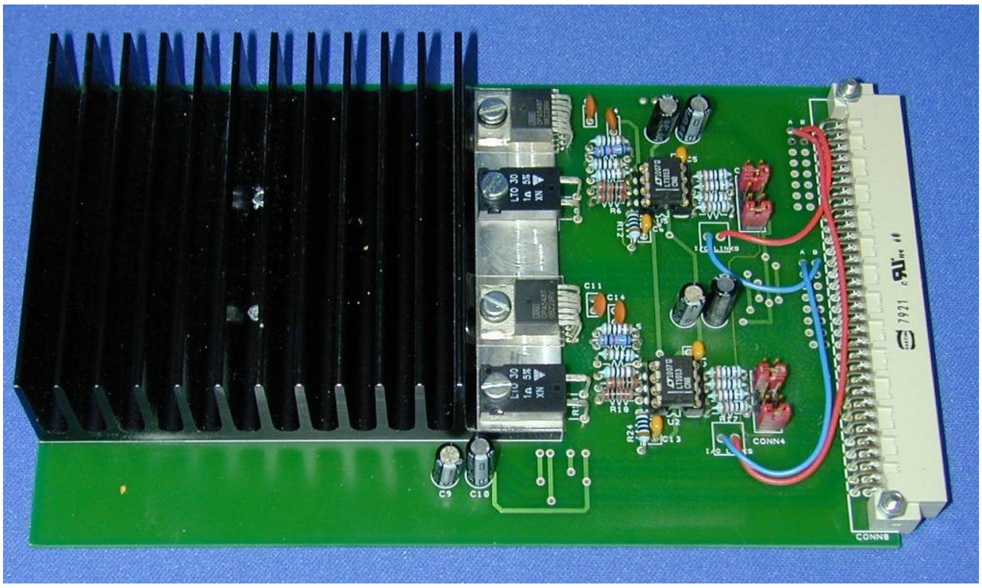

Figure 6. One of the completed boards housing two current source systems. The input current-setting input voltage and the current monitor output voltage are ‘linked’ to Eurocard pins with the red/blue wire connections, as described in the text.

This note was prepared by B. Vojnovic and RG Newman in July 2007 and updated in August 2011. RG Newman designed the boards and constructed the system while S. Gilchrist was involved in their testing.

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