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FILTERING & GNDING

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24 January 1990

ON FILTERING AND GROUNDING WITHIN POWER CONVERTERS

INTRODUCTION.

There are three principle types of Electro-Magnetic Interference (EMI) encountered in spacecraft applications: a) radiated electric fields, b) radiated magnetic fields, and c) structure current noise. In most cases radiated fields are relatively easy to prevent and their effect can be minimized by fairly straightforward electrostatic shielding. Radiated magnetic fields and structure noise are more pernicious; it is much more difficult to immunize circuitry against them and all major efforts must be directed towards their elimination at the source.

Power converters are major sources of these two latter interferences. The main object of this note is to discuss the mechanism of structure current generated within converters, and the means to minimize them. A short chapter at the end will discuss the magnetic field causes.

CONVERTER MODELS - SERIES REGULATOR, SQUARE-WAVE SWITCHING TYPE

We will start with the simplest (and normally the "cleanest") type of converter: square-wave power switching with or without series regulators at the inputs and/or outputs. A very simplified shematic is shown in Figure 1.

The central element of this converter, from an EMC point-of-view, is the power transformer, of which there may be more than one. Generally there is a square-wave present on the input (primary) side of this transformer with a peak-to-peak amplitude of twice the input bus (thus about 60 V). This tends to cause a capacitive current across the transformer from the primary side to the secondary side because of the inevitable inter-winding capacitance. Indeed, this capacitance can (and should) be significantly reduced by electrostatic shielding between the windings but it cannot be completely eliminated.

The resultant current is never negligible. It is this current we must deal with. This is not easy because it is essentially a current source, being generated by a large voltage in series with a high impedance. In this minimally filtered case shown in Figure 1 we see that the current will leave the converter via the secondary ground lines and return via the power lines. Between these two points it will follow the long signal ground path to the star ground and then find its way back to the power system, or perhaps it will be shunted by stray capacitance into structure. It is either the structure or the ground reference, or both, which becomes contaminated. The current must get back to the generator.

Classically this structure current is not measured directly. EMC measurements often consist of measuring only the differential and the common-mode power line currents. In the simplified non-filtered case we have shown here the common-mode current is equal to this current across the transformer. Now if these power line currents are all that is being measured there is an easy way to make them disappear: EMI filters to chassis ground as show in Figure 2. This time all of the current does get onto the structure! While the spec's are met now it is the whole system which is seeing the effects of this current, including the initiator because he still has the return of the current coming back through his signal ground to cope with.

The only way to get rid of this undesirable current is to shunt it back to its source by the shortest possible path. I recommend the use of well-placed capacitors between the primary and secondary grounds for this purpose. Then a series impedance must be inserted on at leasts one side of these capacitors, to make sure that this impedance path is the lowest and to avoid low-impedance ground loops.

Another alternative, which I like less but which I agree is feasible, is to use the EMI filters to chassis, but on BOTH sides of the transformer and close to it, with blocking impedances on both sides to contain the induced structure current to a small portion of the converter chassis. These two solutions are shown in Figures 3 and 4.

ANOTHER TYPE - PULSE-WIDTH MODULATION

There are several ways of making converters which rely on switching power with a variable duty cycle in such a way that the available output power is more or less proportional to the percentage of time the power is switched ON. These are known as PWM converters, which stands for pulse-width modulation. This type of regulator has become very popular in recent years because of the availability of specialized integrated circuits which control this duty cycle. Many of the necessary components are included on-chip, which makes for a compact and easily built converter. Also the converter efficiency is quite high. The PWM converter is also required when the input power bus is not regulated (not the case for GGS). The PWM converter is not very interesting from an EMI point-of-view.

Some PWM converters use a large series inductor as a switched energy storage device. There are large AC voltages present on this inductor and the nearby circuitry which require good shielding and filtering in order to contain them. There is a good possibility of magnetic field radiation. A magnetic shield is needed. Note that this should also be done for the output transformers.

Practically all PWM converters have a variable duty cycle to drive the output transformers. It is therefore more difficult to optimize the driving waveforms and to filter the secondary outputs.

One of the major disadvantages of the PWM converter is that the noise spectrum will change as the power needs change. Thanks to the crystal frequency control the spectral rays will stay at the same positions, but the relative amplitude of the harmonics will change with the duty cycle. This could make the difference between an out-of-spec converter being tolerable or unacceptable.

AC MAGNETIC FIELD GENERATION

AC magnetic fields are generated by the switching transformers, by current loops, and in the case of some PWMs, the switched series inductor.

The transformers and inductors should be well-built, with tight, evenly-spaced windings, and be of a core material well-adapted to the operating frequency. Furthermore, overall shielding of the transformers is highly desirable. This usually consists of both a magnetic shield and an electro-static copper shield.

The current loops can be minimized by careful printed circuit layout of the switching circuitry and by placing the shunt capacitors discussed

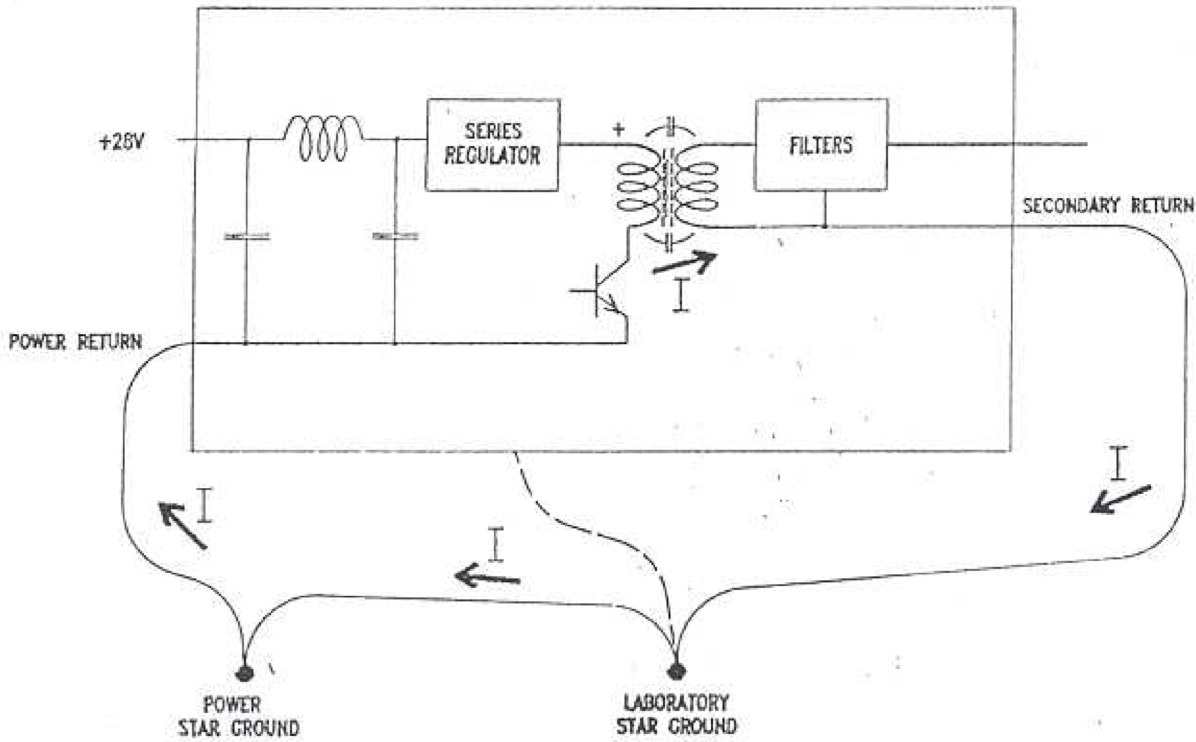

Figure 1.

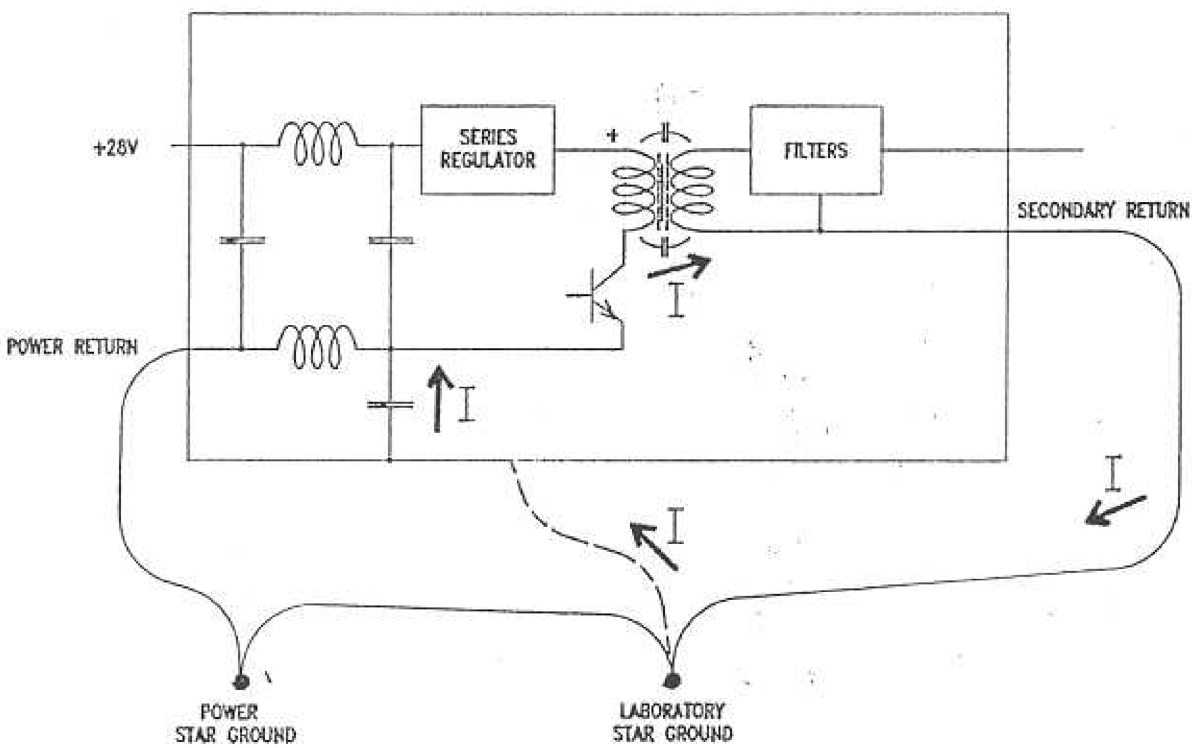

Figure 2.

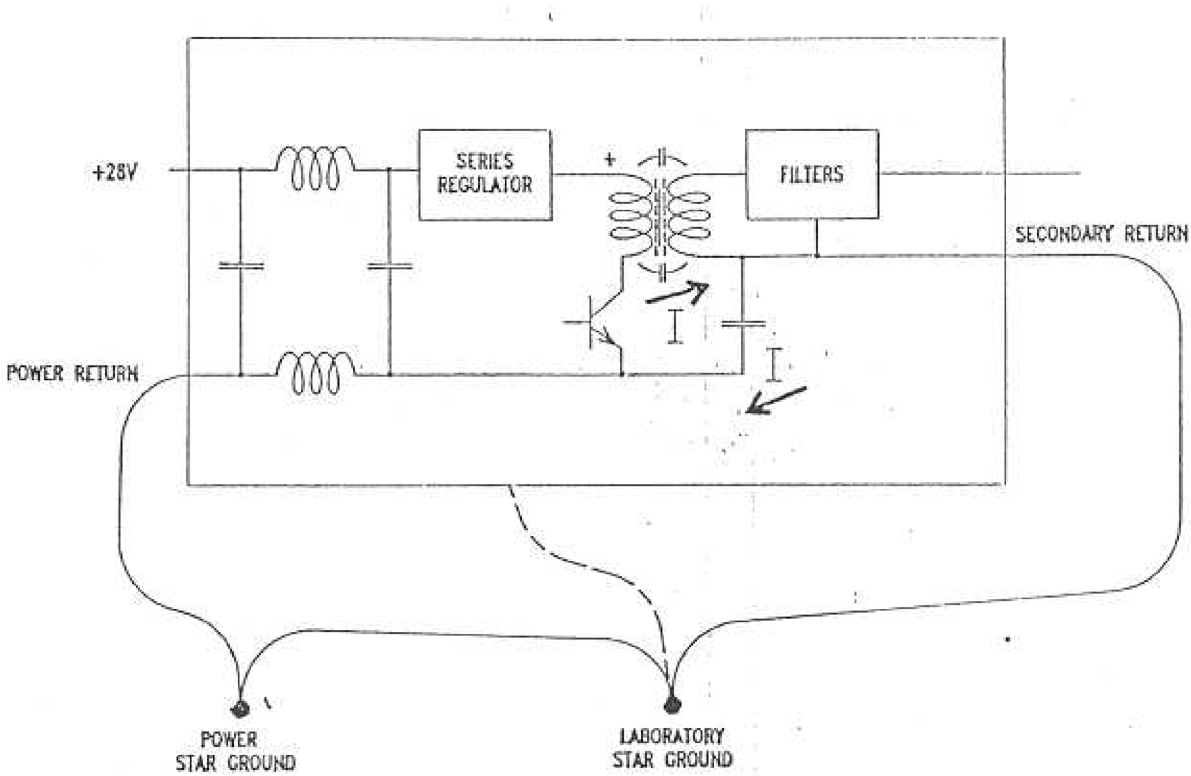

Figure 3.

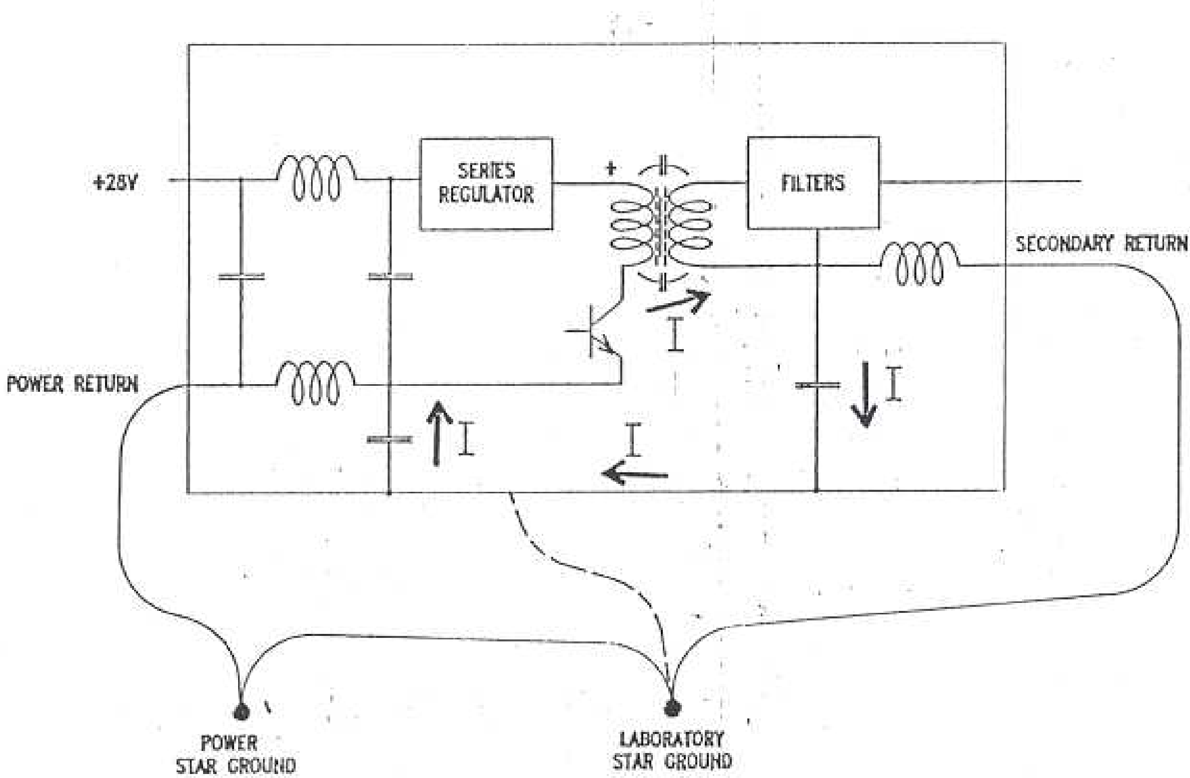

Figure 4.