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CURRENT LIMITING REMOTE POWER CONTROL MODULE

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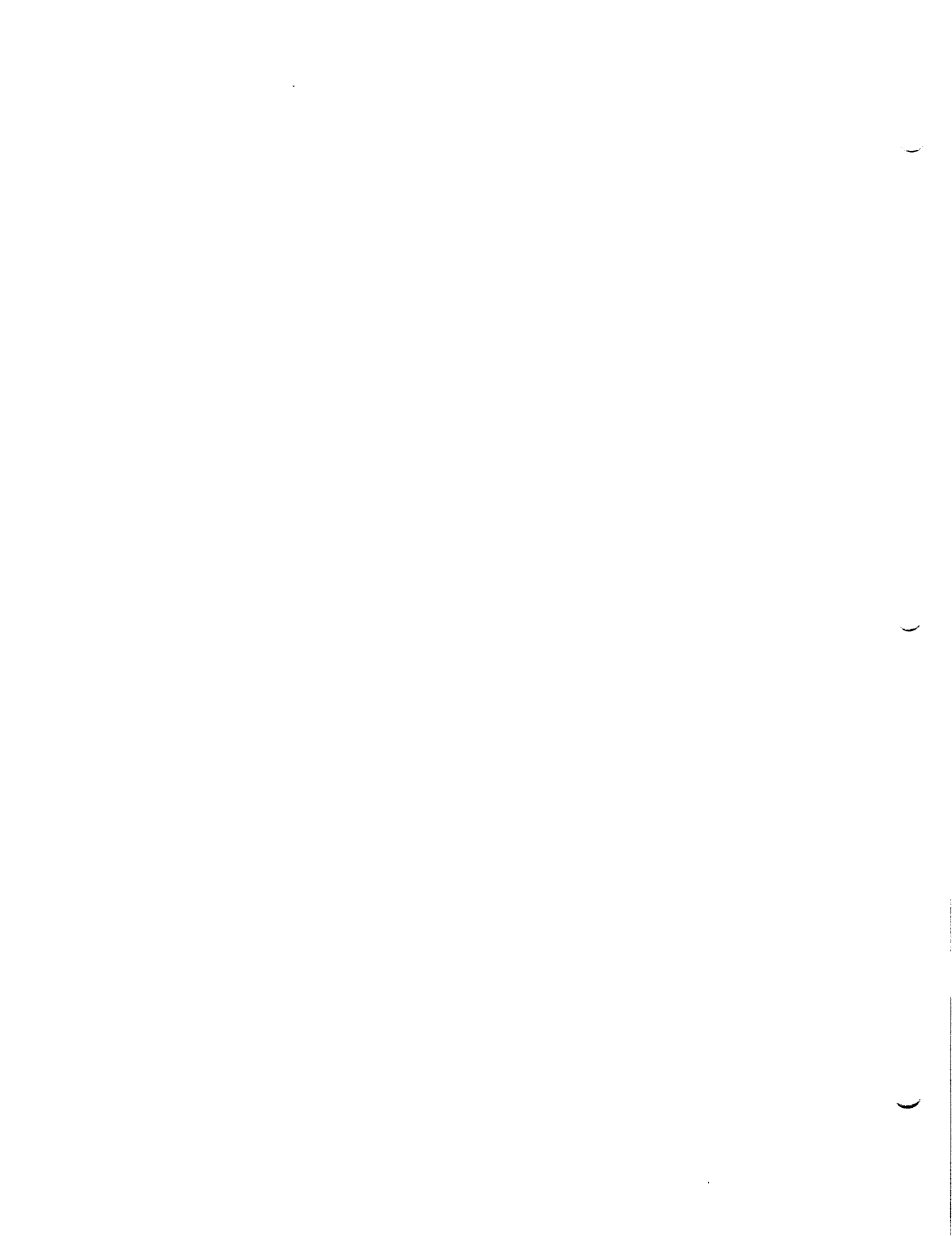
Introduction

The power source for the space station freedom will be fully utilized nearly all of the time. As such, any loads on the system will need to operate within expected limits. Should any load draw an inordinate amount of power, the bus voltage for the system may "sag" and disrupt the operation of other loads. To protect the bus and loads some type of power interface between the bus and each load must be provided. This interface is most crucial when load faults occur.

A possible system configuration is shown in Figure 1. The proposed interface shown is the Current Limiting Remote Power Controller (CL-RPC). Such an interface should provide the following power functions.

    a. limit overloading and resulting undervoltage;
    b. prevent catastrophic failure and still provide for
        redundancy management within the load;
    c. minimize cable heating; and
    d. provide accurate current measurement.

Other supervisory and management functions can be incorporated into the overall RPC. However, the intent of the work here is limited to power processing.
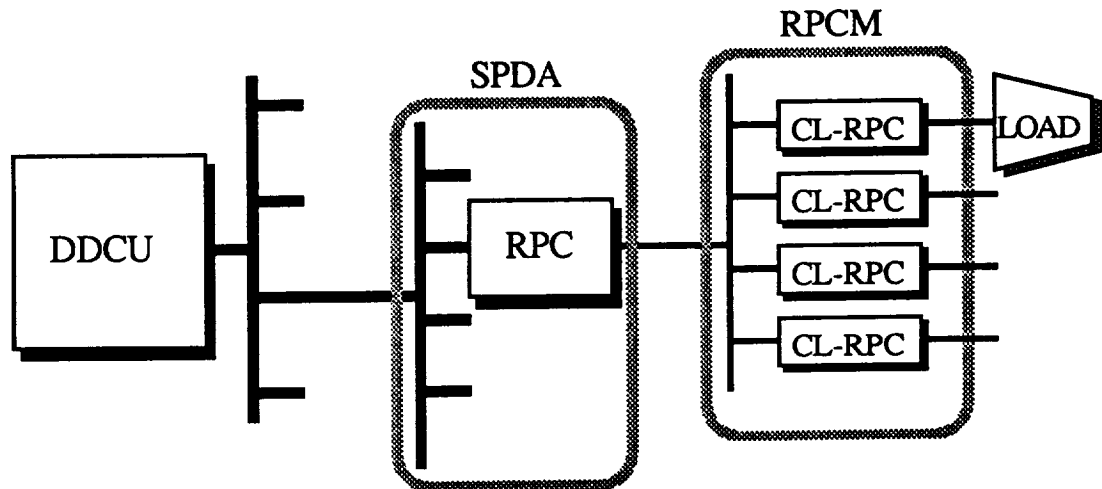

Figure 1. Power system

Design Considerations

A functional block diagram of the power processing stage of a CL-RPC is shown in Figure 2. There are four functions that drive the circuit design.

    a. rate control of current;
    b. current sensing;
    c. the variable conductance switch (VCS) technology; and
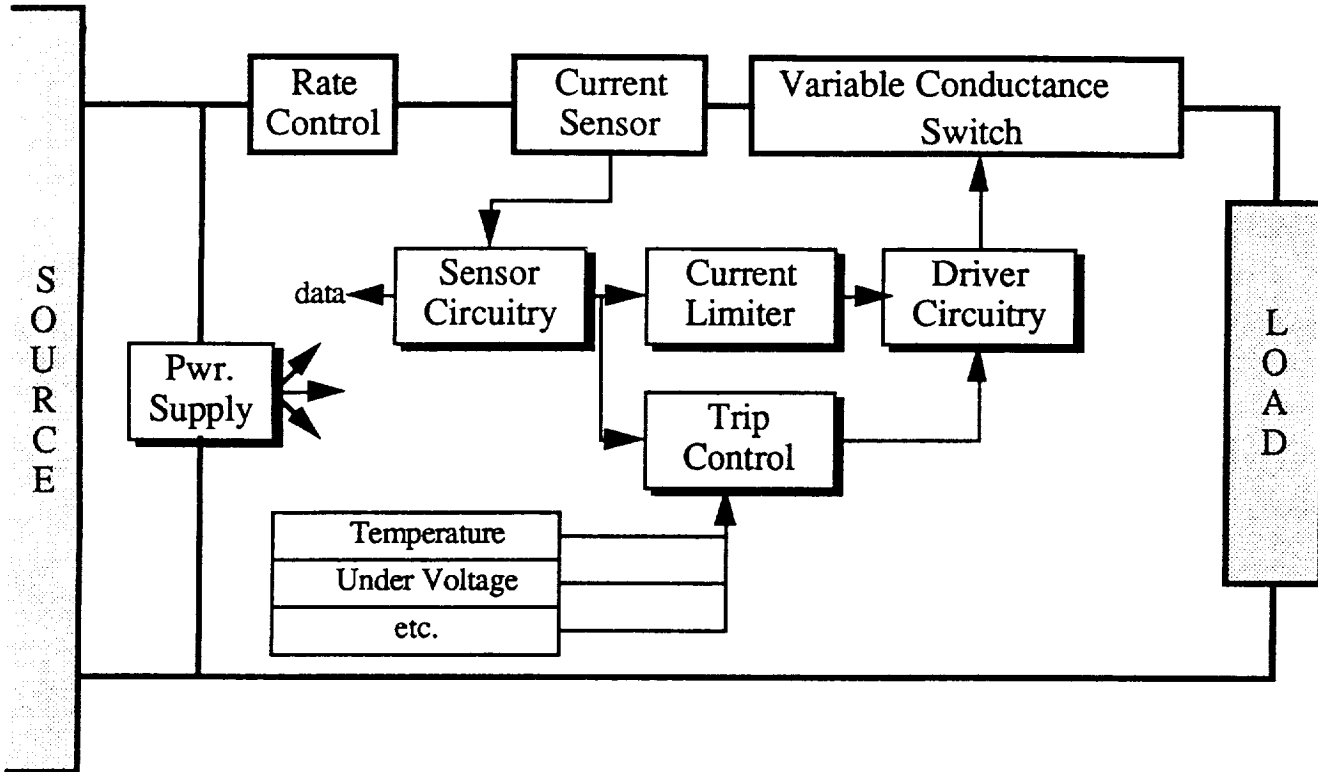
d. the algorithm used for current limiting.

Figure 2. Current Limiting Remote Power Controller

Each function is discussed separately below.

Rate Control

Previous estimates of the bus impedance indicate that there may be as little as 2.5µH in the lines leading from the source to the load. This low inductance will allow a current occurring from a hard fault to ramp at 48A/µs worse case. The time for the current to ramp from 100% to 200% of the nominal RPC design current, and normalized to this value, is 42ns/A. Therefore, a 10A CL-RPC will need to respond in 420ns. The detection and speed of response may be too overwhelming for available electronic hardware. Either custom circuitry or a rate limiter will need to be developed and its effects on the system investigated.

Of particular interest are the ramifications of having varying proportions of distributed inductances before and after the CL-RPC and what effect the ramifications have on the CL-RPC system design. Also, what voltage effects on the system are there during a soft fault and subsequent turn-off of the RPC.

Current Sensing

Sensing methods can be divided into two categories: contact and

noncontact sensing. Regardless of the method, three evaluation criteria need to be quantified: power consumption by the sensor and circuitry (including insertion loss), speed of response, and measurement accuracy. Common contact-sensing methods include a current shunt and semiconductor current-sensing transistors. Common noncontact sensing methods include current transformers (dc bucking type) and optical fiber. An optimum sensing technique can not be determined until the bus system dynamics are well understood and the electrical requirements for the sensor determined.

Variable Conductance Switch (VCS)

The most important design consideration of the CL-RPC is the implementation of the VCS. From initial investigation of the system needs the VCS will need to operate in three modes:

a. Fully on – Typical switch operation with minimum resistance and minimum power loss. On-state voltage drop initially set at 600mV regardless of nominal current level.

b. Current limiting – VCS resistance increases to limit the load current to a specified level. The level is arbitrarily set to 200% of nominal current. The time allotted for limiting is also arbitrarily set and directly determines the thermal design of the VCS.

c. Turn off – The VCS experiences the greatest stress when an overcurrent must be terminated while the VCS is sustaining a high terminal voltage. For semiconductor switches, the SOA parameter will determine the turn off limit.

Typical devices to be investigated for implementing the VCS are BJTs, IGBTs, MOSFETs and MCTs. Of these, the MOSFETs will initially be investigated. Another factor that will impact the implementation is the configuration of the transistors and the modular form of the switch. For instance, a 10A CL-RPC can be made from four 2.5A module in parallel with each having self-protecting current limit.

The power capability of the VCS will not only depend on the size and number of the transistors but also on the packaging and, hence, thermal management. This is a materials issue that has not yet been addressed by this summer's work.

Current Limit Algorithm

The algorithm defines the electrical current versus time operation of the CL-RPC. Under normal conditions the CL-RPC offers little loss to the system and mimics an ideal switch function. During overcurrent operation the CL-RPC will constrain the current to a certain level depending on its own electrical and thermal condition. There are three levels to be determined:

a. Initial peak current – "Nuisance faults," which are of very short time duration, may exceed the current ratings of the CL-RPC. It would be advantageous to allow an initial peak current much greater than nominal to flow during these instances rather than trip or force severe design constraints on the user's equipment. There may also be a need by a user to have a momentary surge of current to clear a fuse or other device to allow for redundancy management. At present, there is no information to suggest what an acceptable level for this current is.

b. Current limit – The initial inrush or charging current of some loads may exceed the nominal current rating of the CL-RPC. Rather than trip off the equipment during starting an overcurrent limit is needed. Again, there is no information to suggest what an acceptable level for this current is.

c. Trip point – This point is reached when a maximum energy has been absorbed by the VCS during current limit. How the energy value is accumulated is yet to be determined. To mimic a circuit breaker the energy is accumulated through an I^2t algorithm. An easier alternate is $\int i(t)\, dt$.

Present Status

Literature Review

A literature search has been performed. The number of citations since 1970 is given below.

"Electronic (&) Circuit Breaker"	321 citations
"DC (&) Electronic (&) "Circuit Breaker"	30 citations
Relevant to 120Vdc	1 citation

Laboratory Results

To determine what factors effect the operation and design of a CL-RPC a hardware implementation has been undertaken. At the time of this report 70% has been completed. The systems requirements used for the design are

Nominal current - 10A
Supply voltage - 113Vdc - 126Vdc
Response time - 1μs
Overcurrent limit - 200%
Trip point algorithm - $\int i(t)\, dt$
Variable conductance switch - six HEX-5 FETs