Power Supply OR’ing Controllers

6.1 What is Power Rail OR’ing?

One method used to increase the reliability of high availability systems is through the use of systems that are powered by two or more (redundant) power supplies. These supplies are generated either by multiple sources or the system is connected to the main supply by the use of multiple paths. Boards connected to these redundant supplies derive a single high availability rail through the use of diodes, as shown in Figure 6-1. This arrangement is called a power rail OR’ing.

![Figure 6-1. N-supply OR'ing Control Using Diodes](image)

This is a simple arrangement. Only the supply that has the highest voltage drives the main board voltage. Also, if the supply voltages are roughly equal, the load power is shared between each source. If a supply fails, the load is transferred to other supplies automatically without any interruption.

Although this is the simplest and most reliable way of OR’ing supplies, this circuit has a disadvantage: it wastes power. Diodes usually drop about 700mV. If the load current is, say, 2A, the power dissipated by the diode is 1.4W. If there are ten boards in a shelf, the power dissipated is 14W, which stresses the cooling system. In addition, diodes that can dissipate more than 2W must be used. These diodes are not only expensive but also are large, requiring more circuit board area.
To minimize the power dissipation, some designs use Schottky diodes. These diodes drop about 400mV, resulting in approximately half the power dissipation. Nonetheless, the dissipated power is still too high, and Schottky diodes are usually more expensive.

Modern power OR’ing circuits use MOSFETs (Figure 6-2) to reduce the power dissipation significantly. Typical turn-on resistance of an N-channel MOSFET is about 25mΩ, so the power dissipated by this MOSFET at 2A is 100mW (2*2*25E-3). In other words, the power dissipation is reduced by 93%.

**Figure 6-2. Power Supply OR’ing Control Using MOSFETs to Reduce Power Dissipation**

When turned on, MOSFETs allow current to flow in both directions. Consequently, a voltage difference between any two rails results in a reverse current flow into the lower voltage supply rail. For example, a 1V difference between $V_{inA}$ and $V_{inB}$ can result in 20A ($1\, \text{V} / (0.025 + 0.025)$) flowing from the higher voltage supply into a lower supply rail. This causes overloading of supplies and, in some cases, damage to the supplies.

To prevent reverse currents, a power supply OR’ing control circuit is required. There are two methods used for preventing the reverse current:

- Monitor current through the MOSFET and turn off the MOSFET, which has less current than the threshold. Current dropping below the threshold can indicate reverse current build up in that limb. If the current in all the limbs is greater than the minimum threshold, all the MOSFETs are left turned on in order to enable load current sharing.

- Monitor the voltage difference between the rails of the input supplies and turn off the MOSFET that is connected to the lower voltage rail. When the voltage difference between the two rails is less than a diode voltage drop, then both MOSFETs are left on, the current to be shared.

The following section discusses positive voltage and negative voltage OR’ing circuits implemented using Lattice Power Manager II devices.
6.3 +5v Power Supply OR’ing (Using MOSFETs) Circuit

The circuit in Figure 6-3 shows OR’ing of two 5V supply rails, 5V_a and 5V_b. The OR’ing control algorithm is implemented in an ispPAC-POWR1014A device. The current through each limb is monitored by the ispPAC-POWR1014A device through current sense amplifiers CSA_a and CSA_b. MOSFETs Q_1 and Q_2 implement the OR’ing function. The common 5V supply rail is derived by combining the drain terminals of Q_1 and Q_2. When both MOSFETs are off, their body diodes provide an inefficient OR’ing mechanism. In Figure 6-3 the OR’d supply feeds a hot-swap controller.

**Figure 6-3. An ispPAC-POWR1014A Device Implementing Two-Rail 5V OR’ing Control**

The circuit starts with both MOSFETs turned off. The load is turned on by enabling the hot-swap controller. When the load starts drawing power, it automatically draws power from one of the MOSFET body diodes. If both voltages are very close, the load pulls current from both the MOSFET body diodes, and both are sensed by the respective current sense amplifiers.

The ispPAC-POWR1014A device turns on the MOSFET on a limb only if the current through that limb is above a threshold value. If the current in both rails is above their thresholds, then both MOSFETs are turned on.

The ispPAC-POWR1014A device continues to monitor the current level in both limbs. During operation, if the current through one of the MOSFETs drops below its low current threshold (due to a sudden drop of...
that power rail’s voltage), then that MOSFET is instantly turned off. When the MOSFET is turned off its body diode blocks the reverse current. Because the MOSFET is turned off when the current drops below the positive threshold, the reverse current that would be driven back into the power supply is avoided. In effect, this circuit implements OR’ing of supply rails through a proactive reverse current avoidance method.

**Algorithm for Implementing OR’ing through MOSFETs**
Step 1 – Wait for at least one of the rails to reach operating voltage value.

Step 2 – Enable the load or the hot-swap controller.

Step 3 – Wait for the load to turn on.

Step 4 – If the current in Limb A is greater than its turn-off threshold, turn on the MOSFET.

Step 5 – If the current in Limb B is greater than its turn-off threshold, turn on the MOSFET.

Step 6 – Wait for either of the currents in the MOSFETs that are turned on in a limb to drop below its turn-off threshold. If the current drops below the turn-off threshold, turn it off and wait for the current to increase above the turn-off threshold, then turn the MOSFET back on. Continue executing step 6.

**Programmable Features**
The following programmable features enable the design described above to meet the needs of a wide variety of OR’ing circuits.

- Individually program thresholds of two comparators to implement hysteresis using a logic equation for MOSFET turn on current and MOSFET turn-off current levels.
- Programmable thresholds for determining the valid input operating voltage range.

**Additional Functions That Can be Integrated into the ispPAC-POWR1014A Device**

- Hot-swap controller – Either soft start or hysteretic current controller.
  - One of the MOSFET drivers can be freed to implement the hot-swap controller by using the transistor circuit shown in Figure 6-4 on page 6-6.
- Integrate sequencing.
- Integrate voltage supervision, reset generation and watchdog timer functions.

**Applicable Power Manager II Devices**
Driving a 5V rail requires a MOSFET drive of 12V. This feature is supported in the ispPAC-POWR1220AT8, ispPAC-POWR1014 and ispPAC-POWR1014A devices.