Design Considerations for Hot Swap

Introduction:

Hot-Swap capability is crucial in many modern electronic devices. Hot-swap refers to the action of replacing a system component while the system continues to run, whilst maintaining normal operation.

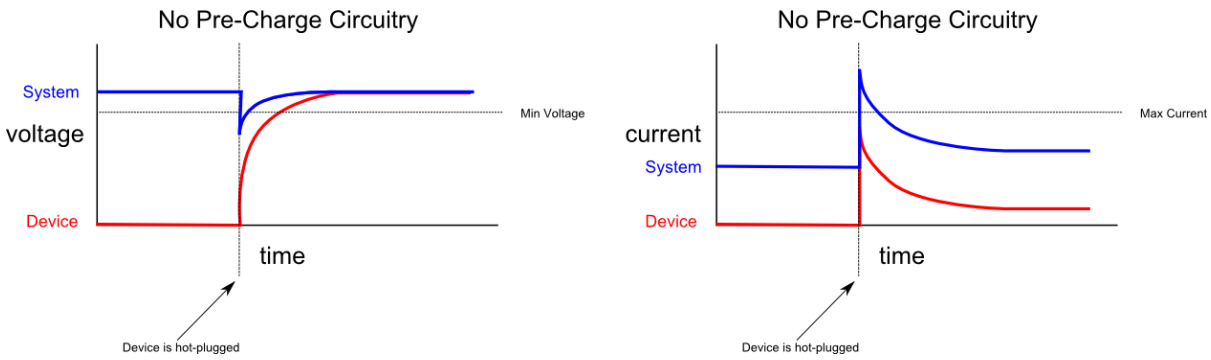
Hot-Swap is a complex operation due to the high level of variability introduced by human and mechanical factors, which must be considered during the design and test phases.

Key Factors:

Pin connection sequence:

A typical device will output signals to a host system given a combination of valid input signals from that host. During a hot-plug operation the pins in a connector system do not all mate at the same time, microscopic differences in pin lengths and contact bounce will result in some signals connecting before others. This behaviour may lead to undesirable system operation and must be properly tested to ensure reliable device operation.

Pre-charge:



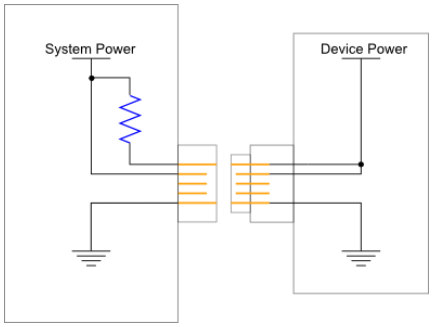
Hot-Swappable components of moderate size must employ some means of pre-charge circuitry to limit inrush current on connection. The un-charged capacitance of a 'cold' device appears as an electrical short circuit to a host system on first contact, this may cause the host system power rails to dip out of regulation or in some cases lead to complete system failure due to over-current shutdown at the power supply.

Design Options:

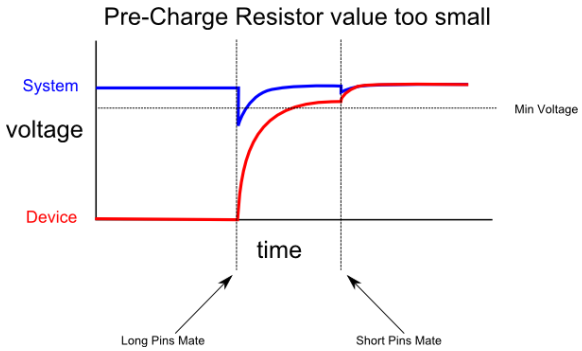
Designers use a number of methods to mitigate the effects of hot-plugging a device:

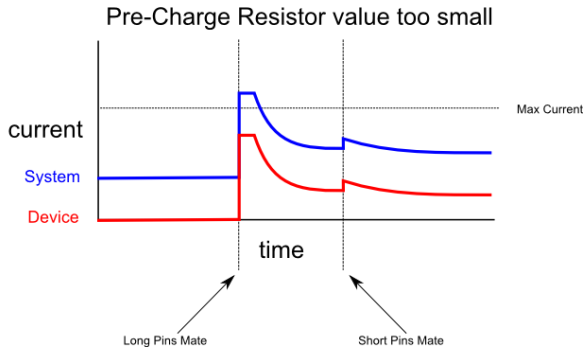
Pre-Charge Circuitry:

A long pin and current limiting resistor may be used to limit inrush current to a device. The long pin mates first; the current limit must be set so that the host system power rails stay within specification, but the device charges up adequately before the power and signal pins make connection.

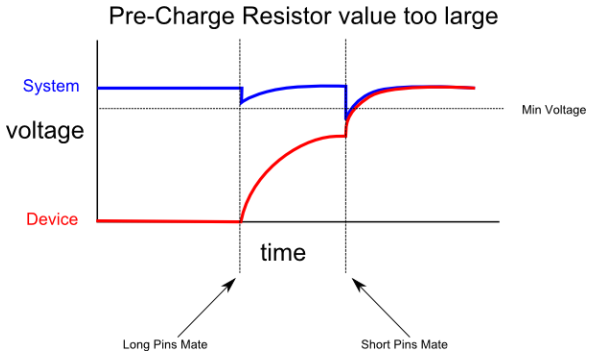


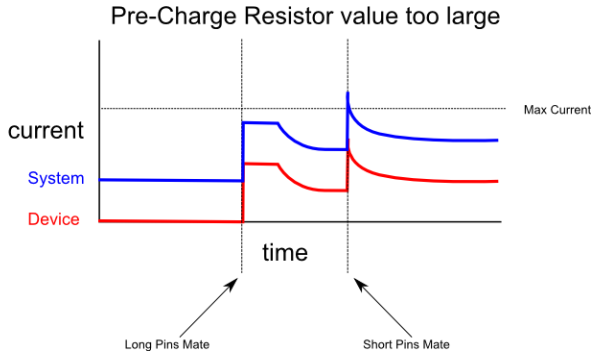
Care must be taken when choosing a pre-charge resistor value, the following scenarios show some common problems:





If the pre-charge resistor value is too small, the device will still draw too much current on insertion, causing the system power rails to drop out of regulation.

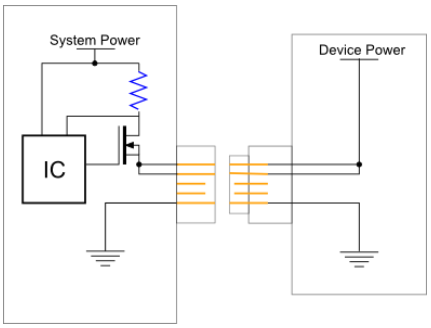




If the pre-charge resistor value is too large, the device capacitance is still not adequately charged before the power pins mate, causing the system power rails to drop out of regulation.

Hot Swap Controller:

A hot swap controller IC controls inrush current to a device. Hot swap controllers typically incorporate electronic fusing, and in high current applications it may be difficult to distinguish between inrush current and a short circuit. The components are more expensive than pre-charge resistors and in some cases the use of more active components in the system may introduce reliability concerns.



Pin Bounce:

Electrical pins within a connector do not mate cleanly on contact with one another; typically a pair of contacts will bounce in and out of connection repeatedly at a microsecond scale before a constant connection is achieved. This behaviour occurs for an insignificant time in terms of human perception but a digital logic system interfaced to such a signal must deal with a large number of events in a short time. Pins also bounce out of sync making the connection sequence unique in each case, this is why 1 in 1000 hot-plugs may fail on the same system.

Mechanical Variables:

(Human factors i.e. speed/ force of insertion)
The primary reason for inconsistencies between hot-plugs is the human factor, it is practically impossible for a human to insert or remove a device with the same velocity and force in a repeatable manner. Differences in the time between pin's mating has a huge effect on the power up profile of a device, making it impossible to reliably test a hot-pluggable device over all its likely operating conditions

Manufacturing Tolerances:

In some cases robotic systems are used to hot swap devices as a time saver – these systems are still unlikely to produce deterministic results due to the tolerance in the actuators and the manufacturing tolerances inherent in each connector
Each system and each connector is subtly different in practice, it is not practical to test every device in existence with every host, so bounds testing should be undertaken to give confidence that the system will operate within expected tolerances. It is impractical to have a hundred connectors made with every possible combination of pin length, insertion force, etc so the solution is to emulate a connector profile with a single programmable fixture.

Solution:

In order to comprehensively test a hot-swap design, it is necessary to create all the possible scenarios in a repeatable way. Placing an interposer module with solid state switches into the system will allow this to be done.

Quarch Technology's solution allows easy hot-swap testing by sequencing the connection of every pin with precise timing.

- Bounds testing can now be run to find the precise failure limits of the system.
- Pin bounce can be added during any connection
- Faults can be injected by failing a pin connection to see how the system responds