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Suppressing Electrical Transients Using Smart Control of the Impedance to Ground

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ABSTRACT

When a device is connected to another using a cable-and-connector, e.g., a USB cable, an electrical transient can occur that can cause damage to the device or put it in an unknown state. This disclosure describes techniques to protect devices from such transient electrical spikes. The ground of the connector is coupled to the ground of the device via one of two paths, a high-impedance path or a low-impedance path. The connector-ground to device-ground coupling is mediated by a software-controlled switch, which defaults to the high-impedance path. When a cable is connected to the device, energy transfer between the connectors occurs via the high-impedance path, thereby forestalling device damage or errors. A short while after the connectors are plugged, the switch switches to the low-impedance path, which puts the device in a normally operative state.

KEYWORDS

- Electrical ground
- Electrostatic discharge (ESD)
- ESD protection
- Electrical transient
- Impedance switching
- Electrical connector
- Software-controlled switch

BACKGROUND

When a device is connected to another using a cable-and-connector, e.g., a USB cable, an RJ-type connector, etc., an electrical transient event can occur. The transient can be caused by electrostatic discharge, by voltage/current spikes (ringing) arising from parasitic, resonant, capacitive-inductive circuits that form upon the mating of the connectors, etc. A transient event can cause large, momentary excursions in voltage and can cause damage to the device or put the device in an unknown state, e.g., cause memory errors. Advances in semiconductors are making possible a decline in the operating voltage of semiconductor devices. Lower operating voltage exacerbates the damage caused by transients, as their peak voltages can dwarf the already small and further declining operating voltage of the devices.

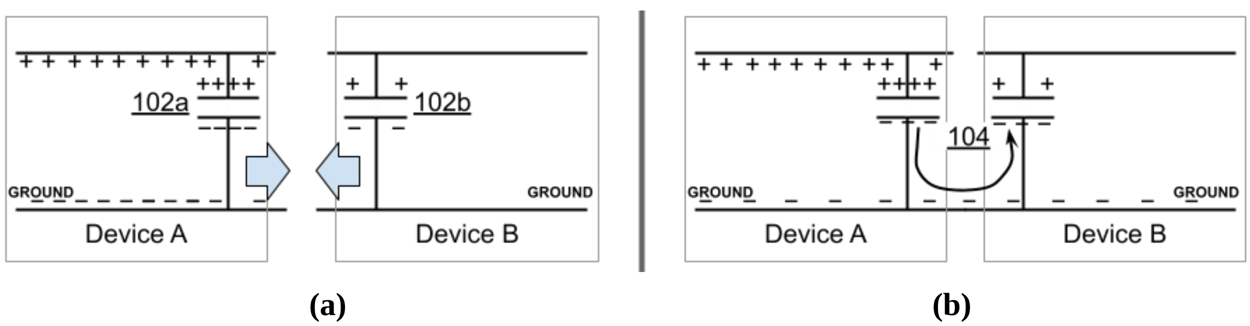

Fig. 1: Origins of a transient event: (a) Just prior to connecting devices A and B; (b) A strong transient current flows just after the ground connection is established.

As illustrated in Fig. 1, transient events can occur at the moment the ground of a male connector (device A) makes contact with the ground of a female connector (device B), at which time capacitive energy (102a-b, Fig. 1a) is suddenly transferred from one ground to the other very rapidly (104, Fig. 1b) as the grounds equalize in potential. Note that both devices typically float above earth-ground, such that their ground pins may not initially be at equal potential, nor will they necessarily be at the potential of the earth. Also, connectors usually have a ground-pin-contact-first design, such that charge and energy transfer occur the moment the grounds of the connectors make contact, e.g., even before the power/signal lines of the connectors make contact.

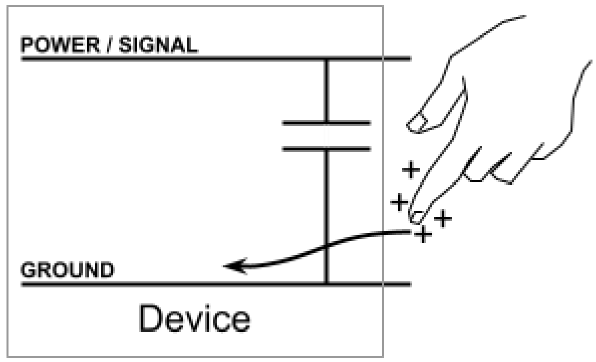

Fig. 2: Electrostatic discharge giving rise to a transient event

Fig. 2 illustrates another mode by which transient events can occur. Static electricity accumulated on a human finger discharges through the device, giving rise to very high (although short-lived) voltages within the device, with the potential to damage or cause errors. In the example of Fig. 2, ESD invades through the ground pin, although it can also invade through power or signal pins.

The connect-to-ground philosophy of most I/O connectors or cables is to minimize the impedance of the ground connection. The low impedance-to-ground optimizes electromagnetic interference (EMI) or radio-frequency interference (RFI). However, at the moment of plugging in a connector, the low impedance enables such an efficient transfer of energy between grounds that a strong, potentially damaging transient event can occur.

DESCRIPTION

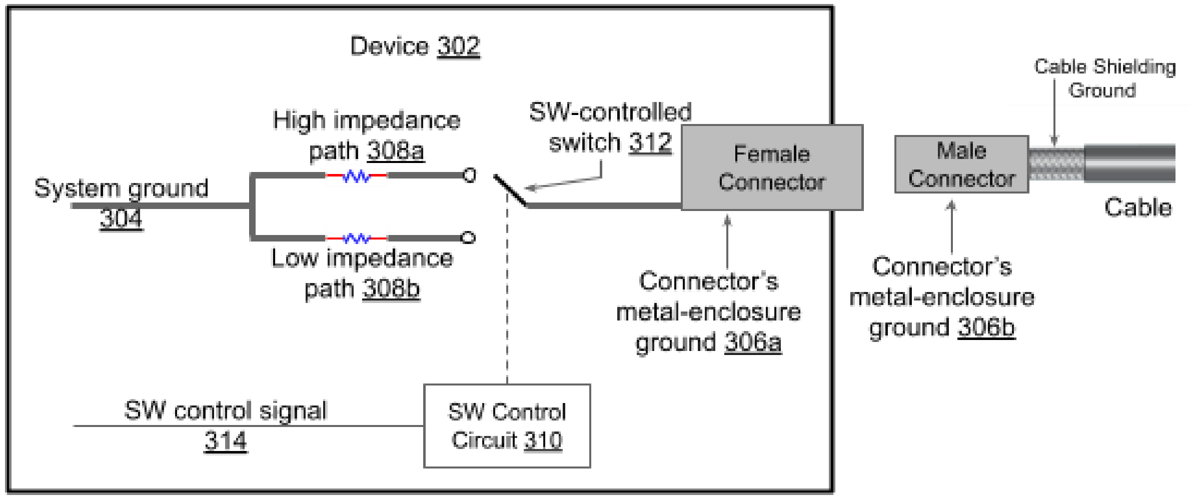

Fig. 3: Suppressing electrical transients using smart control of the impedance to ground

Fig. 3 illustrates suppressing electrical transients using smart control of the impedance to ground. Per the techniques, the ground of the connector (306a, e.g., of female type) of a device is separate from the system ground (304) of the device (302). The ground of the connector can be coupled to the ground of the device via one of two paths, a high-impedance path (308a) or a low-impedance path (308b). The connector-ground to device-ground coupling is mediated by a software-controlled switch (312), which is controlled by a software-control circuit (310). The default position of the switch is the high-impedance path.

When a cable is connected to the device, the ground of the connector of the cable (306b, e.g., of male type) makes contact with the ground of the connector of the device (306a). Due to the high-impedance path to ground, energy transfer between the two (male and female) connectors does not result in a transient spike of high voltage, thereby forestalling the possibility of device damage or errors. Although high enough to suppress transient events, the high-impedance ground-path can provide enough of a ground connection to enable low-speed communication and power transfer.

A short while after the connectors are plugged in and the low-speed (or DC) electrical connection established, the switch switches to the low-impedance path. The trigger that throws the switch to the low-impedance path is a software-control signal (314), which can be, e.g., a hot-plug detect signal, a signal that confirms the mating of the male and female connectors. Switching to the low-impedance path puts the device in an operative state, e.g., with a common ground between the device and its external connection, with normal support of high-speed communication with good-as-normal EMI/RFI performance.

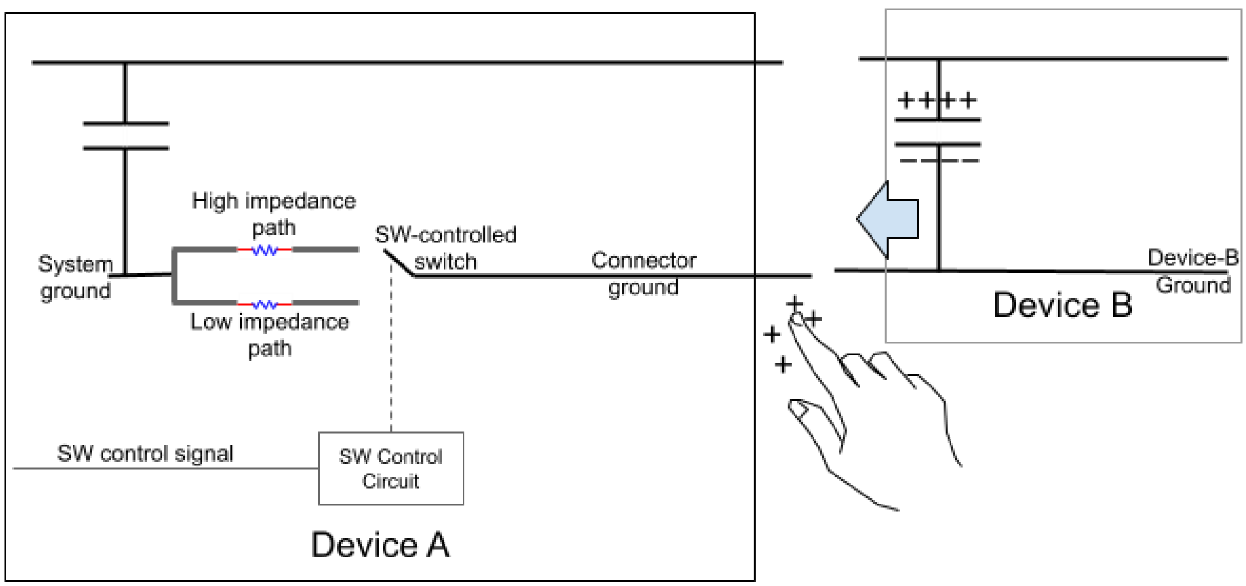

Fig. 4: Electrical schematic of transient suppression using smart control of the impedance to ground

Fig. 4 illustrates an electrical schematic of transient suppression using smart control of the impedance to ground. The ground of the connector of device A is coupled to its system ground via a software-controlled switch with default path set to high impedance. When device B is connected (or when ESD occurs, e.g., due to touch of the human body), a high-spike transient is averted due to the default position of the switch, which is the high-impedance path. After the connection is stabilized, the switch switches to the low-impedance path such that device A can enjoy normal functionality and high-speed connectivity at low EMI/RFI.

In this manner, devices or modules sensitive to transient electrical events, and whose input-output ports need low impedance-to-ground for proper functionality, can be protected from high-spike transient events.

CONCLUSION

This disclosure describes techniques to protect devices from transient electrical spikes. The ground of a connector is coupled to the ground of the device via one of two paths, a high-impedance path or a low-impedance path. The connector-ground to device-ground coupling is mediated by a software-controlled switch, which defaults to the high-impedance path. When a cable is connected to the device, energy transfer between the connectors occurs via the high-impedance path, thereby forestalling device damage or errors. A short while after the connectors are plugged, the switch switches to the low-impedance path, which puts the device in a normally operative state.