Introduction

This technical note will assist you in selecting the correct USB cable for the MCA527. The USB interface is used today nearly everywhere where computers are in operation. USB cables are available from a lot of well-known but also from no-name manufacturers and assumed as standard products with well-defined and guaranteed parameters. This is a great misjudgement! There are cables with different parameters and not every cable can be used for all applications. Some cables on the market don't meet the USB specification under no circumstances and shouldn't be used. Furthermore, the different USB specifications define various connectors which are not completely mechanical compatible to each other. Choosing the wrong cable may result in an unstable USB connection or an undefined device operation. Sometimes the USB device isn't detected correctly by the USB host and cannot be operated. Choosing a cable with wrong plugs always results in no connection.

USB Background Information

Currently, there are three different USB versions, USB1.1, USB2.0 and USB3.0. They vary mainly in speed but also in mechanical definitions and are generally downward compatible. Because USB3.0 defines new standard-B connectors which are mechanically different to USB2.0 and USB1.1, USB3.0 cables cannot be used to operate the MCA527 which has a USB1.1 interface with standard-B socket. Therefore, only USB1.1 and USB2.0 cables with standard-B plug may be used. The cable's type-A plug must mate to the host computer's USB socket (standard-A plug for desktop computers and laptops).

An important feature of the USB interface is the ability to provide power to a USB device. Devices with low power consumption may be completely powered from a USB host or hub. Two conductors of the USB cable are exclusively used for power. The bus voltage is 5V nominal. To avoid overload conditions, the current that a USB device may draw from a USB hub is limited. Every USB device may draw up to 100mA. This is called a low-power function. Because this is not enough power for some devices, the USB specification defines a high-power function, too. High-power devices may draw up to 500mA but only if they are operated on a host or powered hub. Connected to a bus-powered hub they may draw not more then 100mA.

To prevent the USB device from malfunction due to wrong voltage levels, the USB bus voltage V_{BUS} is defined in the USB specification. The voltage supplied by a host or powered hub port must be between 4.75V and 5.25V, for a bus-powered hub port it must be between 4.4V and 5.25V. Therefore, a high-power device must be able to operate with voltages down to 4.75V at the connector end of their upstream cable.

USB devices may have a fixed upstream cable (like a computer mouse) or a type-B socket for a detachable cable (like the MCA527). For detachable cables the USB specification defines the maximum allowed voltage drop of each power conductor (V_{BUSD} and V_{GNDD}). This is important to avoid undervoltage conditions for the USB device. The maximum allowed voltage drop on the V_{BUS} conductor is V_{BUSD} = 0.125V, on the V_{GND} conductor it is V_{GNDD} = 0.125V, too (including both plugs). If a low-power device is connected to a bus-powered hub, then for V_{BUSD} and V_{GNDD} only 0.025V are allowed.

According to the USB specification, high-power devices may be operated only on a host or powered hub. Therefore, the minimum input voltage which high-power devices must tolerate without malfunction can be calculated as:

$$\begin{aligned} V_{min} &= 4.75\text{V} - V_{BUSD} - V_{GNDD} \\ &= 4.75\text{V} - 0.125\text{V} - 0.125\text{V} \\ &= 4.5\text{V} \end{aligned}$$

The MCA527 is classified as high-power device, because it may draw up to 500mA. It works with input voltages down to 4.3V, it has, therefore, a little reserve of 0.2V in a worst-case scenario.

Conductor DC Resistance

USB1.1 and USB2.0 cables have four conductors, two are used as data lines and the other two are used for power supply. The data conductors form a twisted pair with an impedance of 90Ω. Because the current flowing through the data lines is very low, their DC resistance is unimportant.

In contrast, the DC resistance of the two power conductors is very important for proper operation. Unfortunately, the USB specification doesn't define a maximum DC resistance for detachable cables. It defines only minimum output and input voltages and a maximum voltage drop on the cable. Different combinations of powered hubs, bus-powered hubs, low-power devices and high-power devices are possible. This results in different requirements for the power conductor's maximum DC resistance.

In the first scenario a low-power device is connected to a powered hub or host. The conductor's maximum DC resistance may be calculated as:

$$R_{max} = \frac{V_{BUSD}}{I_{max}} = \frac{4.75\text{V} - 4.35\text{V}}{0.1\text{A}} = \frac{0.4\text{V}}{0.1\text{A}} = 4\,\Omega$$

Low-power devices must work with input voltages down to 4.35V and powered hubs must provide voltages greater then 4.75V. This configuration may work properly with cables with up to 4Ω conductor resistance but the resulting voltage drop of 0.4V violates the USB specification which defines a maximum voltage drop for detachable cables of 0.125V. Therefore, a USB compliant cable for this scenario should have a maximum DC resistance of:

$$R_{max} = \frac{V_{BUSD}}{I_{max}} = \frac{0.125\text{V}}{0.1\text{A}} = 1.25\Omega$$

In the second scenario a high-power device is connected to a host or powered hub. According to the USB specification the maximum allowed conductor resistance will decrease to:

$$R_{max} = \frac{V_{BUSD}}{I_{max}} = \frac{0.125\text{V}}{0.5\text{A}} = \frac{0.025\text{V}}{0.1\text{A}} = 0.25\,\Omega$$

This is also the maximum allowed resistance in the third scenario where a low-power device is connected to a bus-powered hub. In this case the maximum allowed voltage drop is 0.025V.

In summary it can be said that three classes of USB cables are possible, but only two of them are compliant with the USB specification. We have tested six arbitrary USB cables and have found cables of all three classes. Table 1 shows the results.

Table 1: Measured Conductor Resistances for Different USB cables

USB Cable	R_{GND}	R_{VCC}	USB compliant
Cable1, 0.9m	0.10Ω	0.10Ω	full
Cable2, 1.0m	0.12Ω	0.11Ω	full
Cable3, 1.8m	0.20Ω	0.19Ω	full
Cable4, 1.8m	0.51Ω	0.65Ω	limited
Cable5, 1.8m	1.91Ω	1.95Ω	no
Cable6, 3.0m	1.02Ω	0.95Ω	limited

Unfortunately, the cables are not classified by the manufacturers. Therefore, it is the users task to find the appropriate cable for their application. This is not easy, because most data sheets specify the conductor's cross-section and material instead of its DC resistance. Table 2 simplifies selection of an appropriate cable. Some cables have different cross-sections for data and power conductors. Usually the conductors with the larger cross-section are used for the power lines. Not all USB cables have copper conductors. Specially some low-cost cables are made with copper clad steel (CCS) conductors, maybe other materials are also used. The conductivity of CCS varies very much. For conductors used in data cables it may be about 20% relative to copper!

Table 2: Calculated Resistances for Different Conductors

Conductor	R @ 1m	R @ 2m	R @ 5m
AWG20, Cu	0,03Ω	0,07Ω	0,17Ω
AWG22, Cu	0,05Ω	0,11Ω	*0,27Ω**
AWG24, Cu	0,09Ω	0,17Ω	*0,43Ω**
AWG26, Cu	0,14Ω	*0,28Ω**	*0,70Ω**
AWG28, Cu	0,22Ω	*0,44Ω**	*1,11Ω**
AWG30, Cu	*0,35Ω**	*0,71Ω**	*1,77Ω***
AWG28, CCS 20%	*1,11Ω**	*2,21Ω***	*5,53Ω***

* *only usable for low-power devices connected to powered hubs*
** *not compliant with USB specification*

Conclusion

Use only USB1.1 or USB2.0 cables with a standard-B plug on one side and a type-A plug which mates to your host computer on the other side to operate the MCA527. The cable shouldn't be longer than 5 meters because longer cables are not compliant with the USB specification. Avoid to use extension cords, they are not compliant with the USB specification. When used, the power conductor's overall DC resistance must not exceed the value required by the application (0.25Ω). Furthermore, the overall length must not exceed 5 meters. Make sure that the conductor cross-section of the two power conductors corresponds with the cable length. Take care about the conductor material. For the MCA527 only copper cables are suitable. We recommend to use a standard USB2.0 cable from TE Connectivity (www.te.com), for example part number 1487596-3 (1.8m) or 1487598-2 (5m).

Do not use active cables (repeater cables). Usually they are bus-powered hubs and cannot operate high-power devices. Do not operate the MCA527 on a bus-powered hub. Actually, this should not work but most bus-powered hubs on the market identify themselves as powered hubs. Under some circumstances the input voltage on the MCA527 can fall below 4.5V and may cause malfunction.

When only a bad USB cable is available, operate the MCA527 with its battery charger. Then the current on the USB power lines decreases to a few milliamperes and therewith the voltage drop on the power lines is negligible.

References

1. Universal Serial Bus Specification, Revision 2.0, April 27, 2000, page 175, http://www.usb.org/developers/docs/usb_20_101111.zip
2. Wikipedia, www.wikipedia.org/wiki/usb/
3. TE Connectivity, www.te.com