DMX Physical Layer

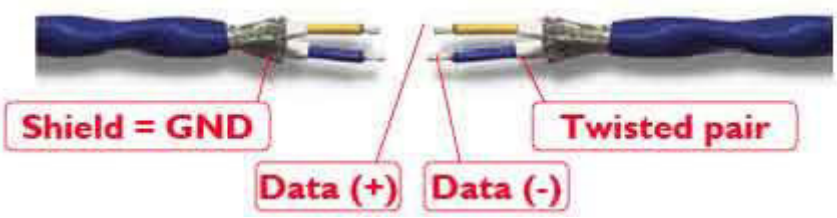
Physical connection to the DMX bus is via a 5-pin XLR connector (often a 3-pin XLR connector is used) or by “hard-wiring” in permanent installations. DMX specifies a 2 pair (4 conductor) cable with a shield (e.g. foil), although only one pair (2 conductor) and shield is required for standard signals (and often this is the only pair that is wired, even for 5-pin connectors).

Cable for Use in DMX-512

DMX-512 uses a twisted pair cable to support balanced transmission using EIA-485 sending asynchronously timed slots.

The type of cable used in DMX-512 has the following electrical properties:

1. A pair of data conductors that are tightly twisted together over the cable length. The pair of conductors must have a characteristic impedance in the range 100 to 120 ohms, 120 ohms is preferred.
2. A ground conductor (sometimes called the "drain") that provides an electrical ground along the length of the cable.
3. A shield that protects the cable from electromagnetic interference. The shield is normally implemented as a foil wrapped around the conductors and in electrical contact with the ground conductor. The standard allows that the shielding to be either around the individual pairs or to an overall shielding covering both pairs, or both of these.
4. Capacitance between conductors within a shield must not exceed 65 pF/m.
5. Capacitance between any conductor and the shield must not exceed 115 pF/m.
6. A second optional pair of data conductors is supported, but defined by the DMX-512 standard.
7. An outer protective (PVC) coating to ease handling of the cable.



Shielded balanced cable, as used for DMX-512

Note: Some application demand specific types of cables, e.g. combining DC or AC power with the DMX signal. Specific applications can use cables with an armoured shield to protect the cable from accidentally being cut (this type of cable is uncommon).

Shielding the cable

DMX specifies the use of screened cable. The primary role of the shield is to protect the signal from electromagnetic interference, especially at higher frequencies where

the twisted pair provides less immunity. A cable screen, earthed at one end helps eliminate radio frequency interference to the bus signals and emissions from the cable. The screen forms a Faraday cage around the cable pair used for transmission.

In summary:

- Receivers must not connect the signal shield/earth to their local ground. This could otherwise result in a ground-loop, adding noise to the received signal.
- Transmitters should ground the shield/earth.
- The ground/shield must be connected at both ends of a length of cable so that electrically this is connected along the entire cable segment, otherwise extension cables joined end-to-end would not be shielded.

Note on Grounding: Each device connects the screen from input to output, but does not connect the screen to the equipment ground. It is important to only earth one end of the bus - usually at the controller or splitter output, to avoid ground loops. DMX-512 optionally allows the data conductors at the transmitter to be referenced to the ground level, but then requires that the total resistance to ground is less than 20 Ohms. Professional interfaces isolate the Data conductors using opto-isolators.

Maximum Permitted Cable Segment Length

The capacitance and resistance per metre determine the maximum frequency that can be sent by the cable without severe attenuation (known as the cable bandwidth).

Lengths of DMX cable may be plugged together end-to-end up to the maximum permitted cable segment length.

Since DMX operates at a baud rate of 250 k baud, the EIA-485 standard suggests a maximum total segment length of 300m. R. educing the number of receivers reduces the load and the cable and low resistance/capacitance cables can be used to driver much greater distances (theoretically up to 1000m with a single sender and remote receiver). However, this may not be possible in practice, and many practical products can not manage to drive a cable of even 300m!

DMX 512 Cable Connectors

Devices to be connected to the DMX cable typically have an input and output connector using male and female plugs. The two plugs on each receiver are wired together so that the electrical signal passes straight through, and the shield is continuous. This ensures that the bus works even if any specific piece of equipment is not powered.

The devices on the bus are connected using cables, which are wired "straight through". The pair of data conductors are wired pin 2 to pin 2, pin 3 to pin 3. The shield is wired pin 1 to pin 1.

Male Female
Pin 1 (screen)---------- Pin 1 (screen)

Pin 2 (Data -)---------- Pin 2 (Data -)
Pin 3 (Data +)---------- Pin 3 (Data +)

Pinout of 3-pin and 5-pin XLR connectors (pins 4,5 are usually unconnected).

Male and Female 3-Pin XLR Connectors

Do Not Use Audio Cables!

The primary reason for using a 5-pin XLR connector for DMX cables is to avoid confusion with audio XLR cables that also use a 3-pin connector. Cables that are intended for use in audio systems (such as microphone cables) often have a 3-pin XLR connector and use balanced cables. However, while these cables have low cost, they do not have a specification that matches the needs of DMX.

Audio signals extend to only a few 10s of kHz, and therefore audio cables often attenuate signals at higher frequencies. This can distort the DMX signal (resulting in attenuation and "ringing"). The result is that these cables provide insufficient signal strength for long cable runs.

Audio cables also do not typically include a shield, since they are not impacted by signals above 100 kHz. This makes them also more vulnerable to interference

EIA/RS-485 Transmitters and Receivers

EIA-485-A uses balanced transmission. The A signal (Data+) and its opposite (complement), the B signal (Data-) are sent using a pair of conductors.

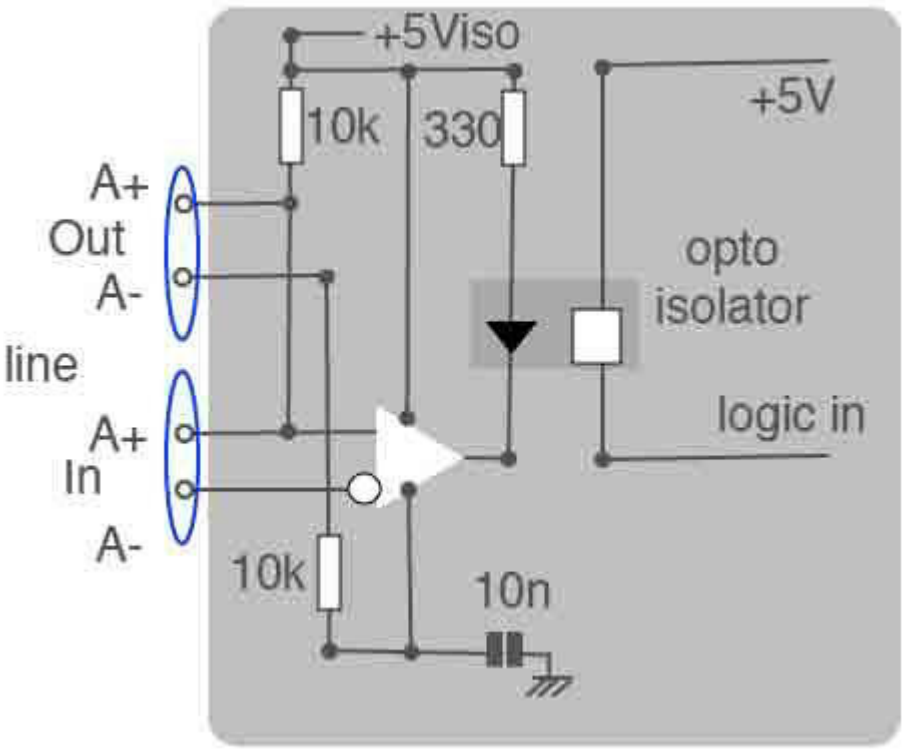
A balanced transmitter drives both the A, B conductor to send each baud:

- A digital 1 is sent out when the A wire is at a higher potential (e.g +5V) than the B wire (e.g. -5V).
- A digital 0 is sent out when the A wire is at a lower potential (e.g. -5V) than the B wire (e.g. +5V).

This format means there is no net radiated signal along the cable length (i.e. the A and B signals effectively cancel one another out). At the receiver this offers good

immunity to external interference (any interfering signal would change both signals equally).

While a simple line driver is sufficient for short-range communications, isolated transmitters and receivers are preferable, because they have much better protection from transient voltages and earthing problems between equipment.



A real-world DMX Receiver incorporating isolation and decoupling of the ground.

Pull-up/down resistors (e.g. 50K-100K) - can be incorporated to eliminate stray signals, by ensuring the positive and negative lines carry a bias current. Capacitive coupling to ground may be included (e.g 10 nF, 1kV) to act as a by-pass for any RF interference.

Grounding and ESD

The cable shield should be grounded at the transmitter (the bus controller). This allows the shield to form a Faraday Cage around the data conductors

To prevent ground-loop currents the cable shield must not be connected to, or be in contact with, the shell or body of a connector or connected to ground at a receiver.

The manufacturers of devices connecting to the DMX cable need to ensure that any pin or contact can withstand a minimum of 4kV Electrostatic Discharge, ESD, for contact discharge and 8kV ESD for air discharge. Suitable optical isolation, transformer isolation, or other means may be used to prevent the undesirable propagation of voltages and ground-loops.

DMX Termination

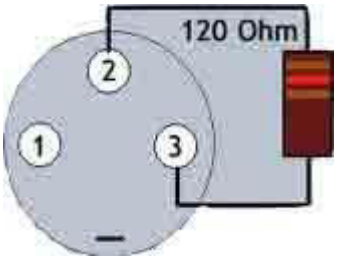
Cable terminations are important for consistent operation.

Both ends of a cable segment need to be terminated with a resistance that matches the characteristic impedance of the cable (120 Ohms). This termination absorbs the transmitted signal, preventing ringing and signal reflection. A termination with this impedance gives the cable the appearance to a node connected that the cable is of infinite length. When the cable is cut to any length (or lengths of cable added to the cable segment) and terminated, measurements will be identical to values obtained from an infinite length cable.

Resistor and cable tolerances, among other things, can result in mismatches between these two impedances. This will result in reflections that increase the noise and can ultimately lead to corruption of data. Similar to radiated emissions, the higher the frequency components and the longer the cable, the more likely it is that reflections will affect the performance.

3-pin and 5-pin XLR Terminators for DMX-512

A DMX terminator therefore has a resistance of 120 ohm +5%/-10% impedance placed between Data+ and Data-. This may simply be a male 5/3 pin XLR plug with a 120 Ohm resistor soldered across pins 2 & 3. In the case where the transmitter cannot be connected at one end of the data link, then both ends of the link need to be terminated (this is required for RDM).



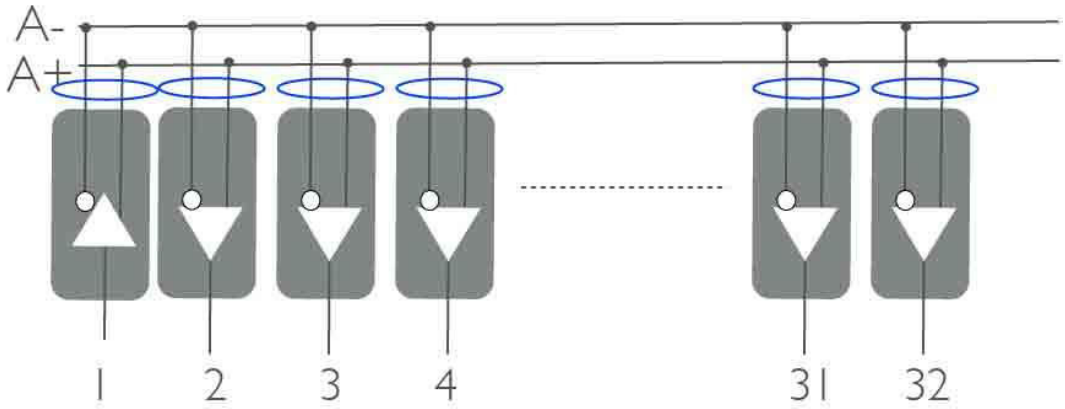
The simplest terminator consists of a resistor. A more sophisticated device incorporates a surge suppressor.

Resistor and cable tolerances, among other things, can result in mismatches between the cable and termination impedances. This will result in reflections that increase the noise and can ultimately lead to corruption of data. Similar to radiated emissions, the higher the frequency components and the longer the cable, the more likely it is that reflections will affect the performance.

Since the termination resistance is a nominal 120 Ohms and the line voltage is 5V this requires a resistor power of v^2/R = 5^2/120 = 25/120 = 0.2W.

Multi-Drop Bus

The maximum number of receivers that may be placed across the control bus is given by the receiver input resistance. In DMX-512 the input impedance of 12 k Ohms restricts this to 32 devices on a single bus. (32 parallel receivers have an overall impedance of 376 Ohms, safe for a cable run up to 300m.)



The transmission standard allows up to 32 receivers to be connected to one cable segment.

A splitter may be used to divide the bus into multiple cable segments. This allows an increase in the cable length and to support more than 32 devices using multiple cable segments per DMX Universe.

Other Cable Types suitable for DMX

Other types of balanced cables may also be used to support DMX-512 in specific cases (e.g. permanent installed wiring): Cat.5 UTP, CAT.5 Shielded UTP STP/FTP, Cat.6 UTP and CAT.6 FTP, S/FTP, S/STP and Cat.7 S/FTP, S/STP.

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