Recommended Practice for DMX512

A guide for users and installers

By Adam Bennette

PLASA

usitt

All the information in this document has been carefully checked; however, no liability is assumed for any loss or damage caused by the use or misuse of any of the information contained herein.

This document is protected by copyright. The copyright prohibits the use of any part of this document for commercial documentation, sales material or other commercial purposes without the express written consent of the Professional Lighting And Sound Association.

No information of a manufacturer or product specific nature has been included and no endorsement or criticism of specific products is implied or intended.

This document has been endorsed by both PLASA and USITT without regard to whether or not the information contained herein may involve patents on materials, articles or processes. By such endorsement, neither PLASA, USITT nor the author assume any liability to any patent owner, nor do they assume any liability whatsoever to parties adopting the DMX512 standard or the Recommended Practice described herein.

Acknowledgements:

I am very grateful to the following contributors, who have made many useful suggestions and comments, for the time and trouble they have taken in assisting in the preparation of this guide: Peter Brooks & Richard Thornton-Brown, Zero88, UK; Steve Carlson, ETI, USA; Bill Florac, ETC, USA; Bob Goddard, Goddard Design Co., USA; Mike Hayward, ARRI, UK; Philip Nye, DHA, UK; Gary Pritchard, LSC, Australia; Ric Salzedo, Avolites, UK; Steve Terry, Production Arts Inc., USA and Ralph Weber, Consultant, USA.

Special thanks to George Thompson of PLASA for all his efforts in co-ordinating the various comments and corrections and for his painstaking proofing and editing of this document.

This document has also been circulated to the PLASA / USITT joint DMX512 working group for verification and I am grateful for all the comments I received.

Adam Bennette, London, 1994

Adam Bennette started in the entertainment industry building pipe organs with electronic guts. He then moved into the field of electronic instruments and soon found himself on tour with Rock bands. After touring around the US and Europe for a number of years he settled down to the design of lighting equipment, and dimmers in particular. Adam has been involved in DMX512 based products since their first introduction in 1986. More recently Adam set-up his own business, A.B. Micro, making DMX512 testing equipment for engineers. At present he is the Lighting Controls Product Manager at ARRI (GB) Ltd.

Contents:

How to use this document

The purpose of this document is to explain the DMX512 specification and to offer examples and professional advice on how to set up a successful DMX512 system. While it also offers advice on certain aspects of the design of actual DMX512 equipment, it does not necessarily contain all the information required to design DMX512 compliant equipment.

This document is a joint PLASA/USITT *Recommended Practice,* not a USITT or PLASA *standard.*

Readers wishing to design DMX512 compliant equipment must also refer to the original DMX512 (1990) standard and the EIA485 (RS485) standard.

This document does not replace the USITT DMX512 (1990) standard, and in all cases where there is any conflict, the USITT standard shall apply. The USITT standard is available for a nominal sum from the address given in the 'Useful addresses' section on page 79.

Parties wishing to participate in the ongoing development and maintenance of the DMX512 standard by PLASA and / or USITT should contact those organisations.

Many issues should be considered when designing a permanent installation, and careful reading of pages 8 to 18 is essential.

A quick summary is provided on page 75 for easy reference.

Nearly all problems encountered by DMX512 users and installers are due to simple cable faults, poor cable layout or interference. There are also a few products on the market which do not conform exactly to the DMX512 specification.

DMX512 protocol:

The DMX512 protocol was first developed in 1986 by a committee of the USITT (U.S. Institute of Theater Technology) as a means to control dimmers from lighting consoles via a standard interface. Before DMX, dimmers were either controlled via individual wires carrying a control voltage or by various proprietary digital or multiplexed analog links.

The analog, wire per dimmer, systems were bulky, expensive and non-standard. They necessitated adapter leads, amplifiers or voltage inverters in order to interface dimmers of one make with consoles of another make. In addition, a fault on the cable or connectors was difficult to repair.

The digital systems available before the widespread adoption of DMX512 were all different and incompatible. Furthermore, manufacturers were reluctant to reveal exactly how they worked for fear of commercial piracy. This left the end-user with very few options. If they wanted a certain console they often had no choice but to use dimmers from the same manufacturer.

DMX512 is not a perfect solution for entertainment control but it is by far the most widely used. Its original design was deliberately kept simple in order to persuade the largest number of manufacturers to adopt it. The simple design was attractive to manufacturers because it reduced the need for large investments or drastic re-design of their existing products.

The shortcomings of DMX512 have been widely discussed in various trade forums and some of these issues are dealt with later in this document. However, most problems found with DMX512 systems result from bad practices or a lack of understanding about what can and cannot be done with a DMX512 network.

Cables:

A successful DMX512 system starts with a good quality cable of the right type. If system reliability is important there is no substitute for good cables and connectors, correctly built and installed. DMX512 can be shown to work on inferior wire, even bell wire, but such systems will one day fail unexpectedly in the middle of an important show.

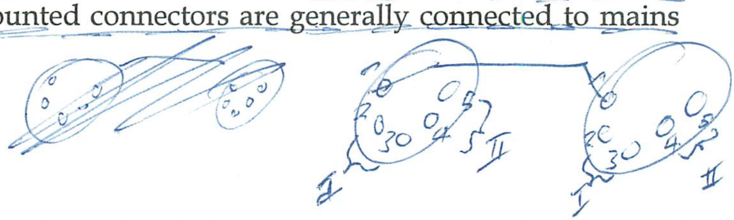
The cable should be suitable for EIA485 (RS485) use, with one or more low-capacitance twisted pairs, with overall braid and foil shielding. Conductors should be 24 AWG (7/0.2) or larger for mechanical strength and to minimise volt drop on long lines.

A second pair of conductors may be present in the cable as spares or to carry other signals. Some dimmers send fault and status information back via these lines. Check if your DMX512 equipment uses this second pair (most do not at present).

When cables are to be laid in permanent installations, or are for rental inventory, it is advisable to use a 2, or more, pair cable as the extra lines are required in order to ensure compatibility with future DMX512 specifications. Some manufacturers are already implementing talkback via these spare wires. The additional pair(s) could also prove very useful if the main pair develops a fault.

The shield is wired pin 1 to pin 1. The conductors are wired pin 2 to pin 2, pin 3 to pin 3. If the second pair is present the conductors are wired pin 4 to pin 4, pin 5 to pin 5. The shield *must* be connected at both ends even if the receiver does not use the ground connection, as otherwise extension cables would not be shielded.

The shield *must not* be connected to, or be in contact with, the shell or body of either the male or female connectors because chassis mounted connectors are generally connected to mains



??? ground and this could cause problems with ground loop currents. (see page 19).

Cable types:

Type:	Pairs:	ZΩ:	Jacket:	AWG	Use:	Temp:
Belden cables:						
1162A	1	100	PVC	20	UL2498	80
1215A	2	150	PVC	26	IBM type 6 office cable	75
1269A	2	100	PTFE	22 (solid)	High temp, Plenum cable	200
8102	2	100	PVC	24	UL2919	80
8132	2	120	PVC	28	UL2919	80
8162	2	100	PVC	24	UL2493	60
8227	1	100	PVC	20	UL2498	80
82729	2	100	PTFE	24	High temp, Plenum cable	200
88102	2	100	PTFE	24	High temp, Plenum cable	200
89182	1	150	PTFE	22	High temp, Plenum cable	200
89207	1	100	PTFE	20	High temp, Plenum cable	200
89696	2	100	PTFE	22	High temp, Plenum cable	200
89729	2	100	PTFE	24	High temp, Plenum cable	200
89855	2	100	PTFE	22	High temp, Plenum cable	200
9182	1	150	PVC	22	UL2668	60
9207	1	100	PVC	20	Flame-proof	75
9271	1	124	PVC	25	UL2092	60
9729	2	100	PVC	24	UL2493	60
9804	2	100	PVC	28	UL2960	60
9829	2	100	PVC	24	UL2919	80

Type:	Pairs:	ZΩ:	Jacket:	AWG	Use:	Temp:
9841	1	120	PVC	24	UL2919	80
9842	2	120	PVC	24	UL2919	80
Proplex cables:						
PC222P	1	110	Poly-urethane	22	Heavy duty and portable	105
PC222T	1	110	PVC	22	UL2464	105
PC224P	2	110	Poly-urethane	22	Heavy duty and portable	105
PC224T	2	110	PVC	22	UL2464	105
PC226T	3	110	PVC	22	UL2464	
Alpha cables:						
9109	1	100	FEP	20	High temp	150
9816	1	95	PVC	18	Large diameter	80
9817	1	100	PVC	20	UL2498	80
9818	1	100	PVC	20	UL2498	80
9818D	1	100	Poly-ethylene	20	Direct burial	80
9821	1	124	PVC	25	UL2092	80
9823	1	150	PVC	22	UL2772	80

This table is not an exhaustive list of all the cables suitable for DMX512. Any *twisted pair, 120ohm, shielded EIA485 cable* is suitable. The required cable gauge will depend on the length but it is recommended to be 22 AWG, 24 AWG minimum.

ZΩ is the characteristic impedance, see termination section on page 12.

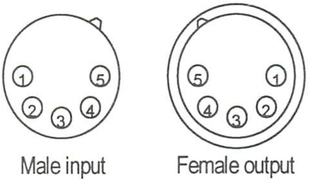
AWG stands for American Wire Gauge.

The above cables are available from electrical suppliers and specialised theatrical equipment suppliers. For addresses of cable manufacturers please see page 79.

Connections:

DMX512 lines connect with equipment via XLR 5 pin type connectors. A female connector is fitted to a transmitter and a male connector to a receiver. DMX512 specifies a 2 pair (4 conductor) cable with shield, although only one pair (2 conductor) and shield is required for standard DMX512 signals. The second cable pair is reserved for unspecified optional uses. See page 8 for other considerations involving the second pair.

pins viewed from outside



pin	wire	signal
1	shield	ground/return/0V
2	inner conductor (usually black)	data complement (-, inverted)
3	inner conductor (usually white)	data true (+, non inverted)
4	inner conductor (usually green)	spare data complement (-, inverted)
5	inner conductor (usually red)	spare data true (+, non inverted)

The 5 pin connector is described in the original USITT DMX512 standard and should be the preferred connector type.

Some equipment may be fitted with 3 pin XLR connectors to allow the use of standard microphone cables, and in this case the pin-out is the same as the first three pins shown above.

The use of 3 pin connectors is not recommended and is not part of the USITT DMX512 standard.

Microphone and audio cables are not suitable for DMX512 transmission. It is strongly recommended that only cable suitable for high-speed data transmission, such as one of the types listed above, is used.

It should also be noted that DMX512 signals may be routed down other cabling systems, for instance to colour changers, typically via 4 pin XLR style connectors. The same rules apply regarding cable characteristics and generally this will require the use of cable specially designed for this purpose.

Termination:

Incorrect or missing termination is probably the single most common reason for faulty DMX512 systems.

The terminator is a resistor fitted between the two data lines (pins 2 & 3 of an XLR 5 pin connector) at the end of the cable furthest from the transmitter.

If a terminating resistor is not fitted, when the signal arrives at the far end of the line it is 'reflected' back down the line to the transmitter. At certain line lengths and conditions the reflected signal can cancel out the real signal, resulting in errors. A terminator resistor 'soaks away' the signal at the far end of the line, preventing reflections.

The resistor value is typically between 90-120 ohms ¼ watt. Strictly according to the EIA485 specification (see page 42) the line should be terminated at both ends with 120 ohms. However, as DMX512 systems are invariably used with the transmitter (i.e. the console) at one end of the line it is only necessary to fit termination at the far end.

It is recommended that all DMX512 systems are built with the console at one end of the line, and the terminator at the other end.

The termination resistance should ideally match the 'characteristic impedance' of the cable (see column ZΩ in the cable lists on page 9). The characteristic impedance is the impedance of a line of infinite length, which, by definition, would not suffer from reflections. Placing a resistor equal to the characteristic impedance at the end of a line of finite length causes the cable to behave as if it were infinitely long, from the transmission circuit's point of view.

Cables for DMX512 have a characteristic impedance of 85-150 ohms approx. RS422 (a predecessor of EIA485) is optimised for 100 ohm lines, EIA485 for 120 ohm lines. As both RS422 and EIA485 transmitters exist in the field, an ideal cable is Proplex PC22xx/x as this has a characteristic impedance of 110 ohms. This cable terminated with 110 ohms represents the best possible compromise for use in the field, although any value between 90 and 120 ohms will work satisfactorily.

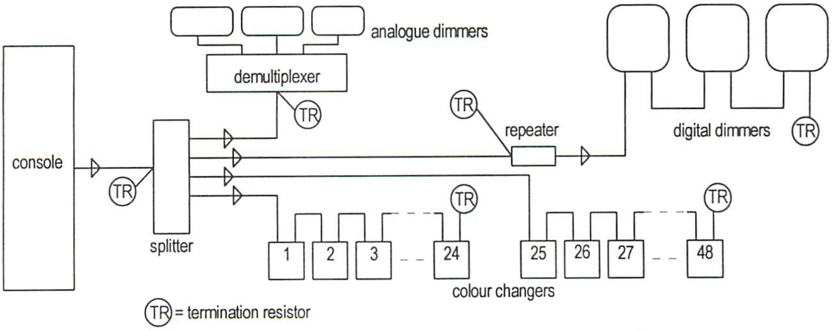
DMX512 systems may appear to work fine without the terminator resistor (indeed it may be forgotten or lost without anyone noticing at first) until they unexpectedly fail.

Always check for the presence of the terminator resistor. A simple resistance check at the transmitter end (disconnect the cable and measure resistance between pins 2 and 3) can reveal the presence of the terminator resistor, or faulty (too much or too little) termination. This resistance should be around 90-120 ohms on short or heavy-gauge cables and may be higher with very long cables due to the additional resistance of the cable conductors themselves.

Some devices are fitted with a switch to select an internal terminator. This switch may be labelled 'end-of-line' or 'last-rack'. It should only be switched in on the last device on the line.

Another common type of terminator is an XLR male plug fitted with a resistor which can be plugged in to the output of the last device. This is simply a male 5 pin plug with a 120 Ω resistor soldered across pins 2 & 3. Every lighting electrician's toolbox should include one of these 'dummy plug' terminators.

Example DMX512 network showing termination resistors:



Network ⇒
splitter
repeater

DMX512 Networks:

DMX512 will only function correctly, especially with long cables, when a single line is employed from the transmitter to the last receiver. A line can have up to 32 unit loads (less if the receivers do not comply with the EIA485 spec. - see 'Optical Isolation, page 19) hung off it anywhere down its length. A typical EIA485 receiver represents approximately one unit load. These devices should connect to the line with very short (less than 30 cm - 12") cables in order to prevent the creation of 'Y' splits (see below), but in practice this length can be extended to several metres. This is normally accomplished inside the devices which, if fitted with input and output connectors, can be daisy-chained together.

The EIA485 link as used by DMX512 is capable of operation on lines of up to 1km (3281') in length. This is the recommended maximum. In practice it is prudent to keep the line length below about 500m (1640'), beyond which signal amplifiers (repeaters) should be considered.

When very long lines are employed, care should be taken to select a cable with sufficient conductor cross-sectional area. The resistance of the cable should still allow at least 0.2V to be developed across the 120 ohm terminator resistor at the far end of the cable when driven with as little as 2 V at the transmitter. Do not use a cable with conductors less than 22 AWG. in size on long lines. The d.c. resistance should not be confused with the characteristic impedance. D.c. resistance can be measured with a standard ohmmeter and should not exceed approx. 200 ohms per conductor.

DMX512 lines should be kept away from power cabling, particularly load cables from dimmers, and should not be run in conduit or trunking with power cables or cables carrying large currents as this could cause interference and errors.

Do not use 'Y' leads / 'DMX Twofers'

A 'Y' lead is a hard-wired connection between a male (console-side) connector and two female (dimmer-side) connectors; all pins 1 are joined, all pins 2 etc.

If 'Y' leads are used, particularly at a distance from the transmitter, then a complex set of reflections will ensue, causing severe signal degradation and increased error rate.

Splitter amplifiers are the only reliable method for splitting the DMX512 network into different branches.

Repeater and Splitter / Distribution amplifiers:

Repeaters:

When very long lines are employed, or more than 32 devices are required, it is necessary to boost the signal through a repeater amplifier, also known as a buffer amplifier. The input of the repeater amplifier is like the input of any other DMX512 device; the output is like that of any other DMX512 transmitter. The line from the console should be terminated in the normal way - the repeater need not be at the end of the line. The second, repeated, line is also terminated at the far end.

Lines can be repeated in this way many times before re-generation errors occur, providing that the repeater amplifiers, and particularly opto-isolated circuits, are sufficiently fast. If these circuits cannot reproduce the rising and falling edges of the signal without some distortion or delay, the chaining together of such devices will eventually corrupt the signal.

Repeater amplifiers only restore the electrical levels of the DMX512 signal, they do not re-create the timings between the individual bits. Re-generation of the timing can only be achieved with special equipment that decodes the DMX512 input and then re-transmits it through a separate encoder (UART) and output driver circuit. Such devices can also be used to modify the DMX512 timings in order to allow the use of non-compliant DMX512 receivers with modern fast consoles (see page 51).

Built-in repeaters:

Many devices, particularly colour changers and large dimmer racks, have built-in repeater amplifiers to re-generate the DMX512 signals. These designs are usually fitted with a relay to switch the input directly to the output in the event of power failure or malfunction so that subsequent units are still fed with data. Note that this switch-over is purely mechanical and is not synchronised to the DMX512 data. As the contacts change-over there will be a brief loss of signal. Devices down-line from the changeover may receive bad DMX512 data. This will not be corrected until the next new packet of levels arrives. Thus, with a slow console the wrong dimmer levels may persist long enough to be very noticeable.

When the repeater is active, each output is driving a 'new' DMX512 line, which should be terminated in the normal way. However, if these lines are very short, e.g. to the next module in a rack, termination would not normally be necessary. Still, it is desirable for the following reason. When the outputs are routed directly from the inputs, if the module is off or has failed, the termination is also removed, thus the next module will provide the termination. The last module would have a terminating plug in its output socket. If all the modules in the rack are off, or have failed, the line will be terminated into the plug. With such a system any other devices will always see a correctly terminated line.

If in doubt about presence of in-built repeaters, and how it can affect the network, try measuring the termination resistance while cycling power on each of the devices on the line. The resistance should remain substantially the same (100-120 ohms) and other devices down-stream should continue to respond to DMX512 levels, although there may be glitches in their operation, as described above.

Splitters:

Splitter amplifiers are like repeaters but they have more than one output. Each output drives the same signal but down separate lines. These are also known as distribution amplifiers as they allow the DMX512 line to be replicated and sent in different directions to devices distributed throughout a building or concert site.

There are important differences between isolating and non isolating repeaters and splitters which are discussed below (see page 19).

Connection of pins 4 & 5:

The second pair in the DMX512 line is described in the DMX512 specification but its use is not defined. There are many devices and systems in the field that use the second pair, on pins 4 and 5, for various purposes. Some systems implement talkback using the pair as a return EIA485 line to the console or a separate fault and status display unit. Other systems may employ the two wires of the 2nd pair as direct control signals, for temperature indication for instance.

Most DMX512 devices, with in and out connectors for daisy-chaining, simply connect the first three pins; 1 to 1, 2 to 2 and 3 to 3. Not all devices also connect pins 4 to 4 and 5 to 5.

Talkback systems which utilise the second pair as a return line require special distribution amplifiers and custom bi-directional repeaters and isolators.

Network Isolation:

Grounding:

In the manufacture of DMX512 equipment, there is no accepted standard for connection of the signal common, or line ground, to the mains/chassis ground. The EIA485 standard requires that the line ground be tied to the mains ground in both the transmitters and receivers, unless the common-mode voltage does not exceed the specified values (see page 42). In practice this means that manufacturers sometimes connect to mains ground and sometimes leave the line ground floating.

The ground wire of the line should be connected to mains ground at the transmitting end in most DMX512 installations (except battery powered transmitters, testers etc.) for reasons of interference rejection and electrical safety legislation. In a standard EIA485 set-up the line ground may also be connected to the receiver mains ground. This can cause special problems with large lighting systems, ranging from signal errors to catastrophic failures.

It is important when installing a DMX512 network to determine which units have their DMX512 cable shield connected to mains ground and which do not. This can be ascertained with a simple continuity check between pin 1 of the device's connector and mains or chassis ground.

If all the devices (except the transmitter / console) are isolated from ground it will not normally be necessary to take any special precautions. If one or more devices are grounded it may prove necessary to install isolation circuitry to part or all of the DMX512 network.

Data errors caused by poor grounding:

When equipment is widely separated in different sites in a large building, or outdoors, there can be quite large voltage differences between the local grounding points of each site. These are due to currents flowing in the ground cables back to the common ground point, which may be located at a great distance, e.g. the sub-station transformer.

EIA485 specifies that the receivers and transmitters can tolerate up to +12V or -7V 'common mode voltage'. This is the voltage that can be applied safely between a data wire and the local ground point for that receiver or transmitter. If the common mode voltage is exceeded the EIA485 devices will certainly produce errors and may eventually fail.

Safety problems caused by poor grounding:

If a fault develops to ground, for instance in a luminaire, and the ground of the dimming system is faulty, the fault current will flow back to ground down the only remaining ground connection - the DMX512 cable shield. Large enough fault currents can cause the DMX512 cable to explode - literally ! Furthermore, such a fault would be very likely to destroy all the circuits connected to the line (*this really does happen*). When transmitters and receivers (console and dimmers) are located in close proximity and connected to the same mains supply such a situation is unlikely in practice. The problem is more severe when the dimming equipment is fed from a separate supply, or worse still a generator with inadequate grounding.

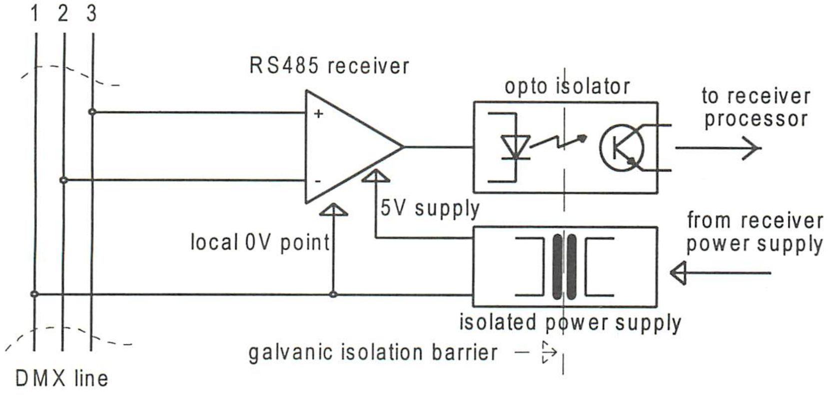
Optical-isolators for proper grounding:

The solution to the grounding problems described above is to disconnect the receiver ground from the DMX512 line ground / 0V wire, by means of an optical isolation circuit. This technique will completely eliminate errors due to high common mode voltage and will offer some protection against severe faults.

This is achieved in the following way:

The signal is received by a EIA485 circuit which then feeds this signal through the optical isolation circuit. The EIA485 circuit is fed by an independent power supply and no part of this circuit is connected to mains ground. Because the input is a real cuit is connected to mains ground. Because the input is a real EIA485 receiver the line can accept up to 32 such devices, assuming that each one represents one standard unit load.

Correct practice for opto-isolated receiver circuitry:



There exists a second method which uses a sensitive optical isolation circuit directly on the DMX512 line, between the data wires. This is known as Direct-on-line (DOL) or Current Mode, and in this mode the ground/return/0V wire is not connected at the receiver. *This type of circuit is not true EIA485.* It loads the line with the equivalent (approximately) of anything between 3 and 10 normal EIA485 devices. Thus only 10, or less such devices could be used on a single DMX512 line.

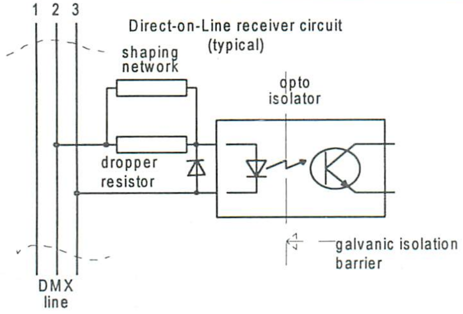
The DOL method has a number of serious drawbacks;

- Only a small number of such devices can be accommodated on one line, in some cases just one device.
- The presence of these devices on the line is likely to cause other, standard EIA485, devices to malfunction.
- Increased error rate.
- Malfunctions on long cables or small gauge cables

Direct-on-Line opto-isolators do not conform to the EIA485 standard and will cause problems in DMX512 installations.

If DOL devices are used on the same line as true EIA485 devices, problems can arise. The DOL devices distort the voltage waveform. This can cause the EIA485 devices to produce errors. The safest use of a DOL device is as the only receiver, or a small number of receivers, at the end of the line.

Bad practice for opto isolated receiver:



There are some products which use a Direct-on-line opto-isolator, typically 6N137 or equivalent, which will load the line very heavily.

These designs should generally only be used as the single receiver at the end of the line.

If you think that you have some DOL devices, check with the manufacturer to determine their line loading characteristics. If you must use a device with DOL isolation it is advisable to feed it from its own DMX512 line by means of a splitter or repeater amplifier in order to prevent failures and errors on the rest of the DMX512 network.

Both repeaters and splitters are available from a number of manufacturers which offer opto-isolation between input and output, and in some cases between individual outputs. A fully isolated splitter can prevent severe faults from propagating through an entire DMX512 network and ensures that common mode problems and other failures are limited to a single branch of the DMX512 network. A fully isolated splitter requires a separate source of isolated power for each of its output circuits. A simple continuity check between pin 1 of different outputs will reveal if the outputs are isolated from each other.

The presence of opto-isolation in a DMX512 network does not guarantee protection from damage caused by severe faults.

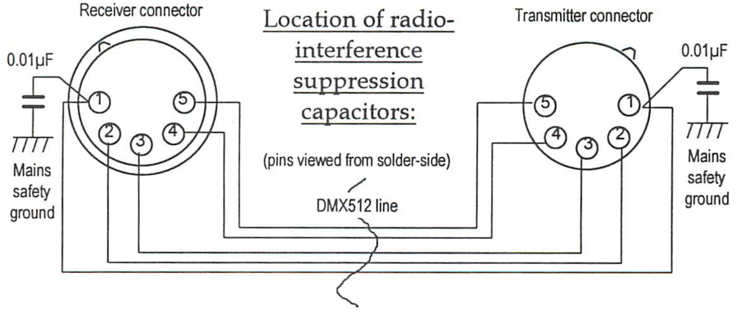
If sufficiently high voltage is applied to the DMX512 line any devices connected to it may fail catastrophically and allow the high voltage to enter the equipment. The presence of opto-isolation does not reduce the need to take normal precautions for adequately insulating power lines and data lines from each other.

Radio Interference Suppression:

Sometimes, you may experience DMX512 data errors when radio transmitters are operated in proximity with DMX512 lines. Most probably, some of the radio energy is getting in to the DMX512 line and interfering with the receivers.

A simple remedy is to fit a small-value capacitor between pin 1 (DMX512 0 V/shield) and mains ground, a 0.001µF-0.01µF (1-10 nanoFarads) capacitor should suffice. For increased immunity from interference a small 'spark-gap' component may also be fitted across the capacitor, this will protect against excessive voltages and may also provide some electro-static discharge protection.

These measures will only be possible when the receivers are optically isolated (see previous section) and, generally, should be applied at a number of points on each DMX512 line. The capacitor should be of a type designed for high frequency interference suppression.

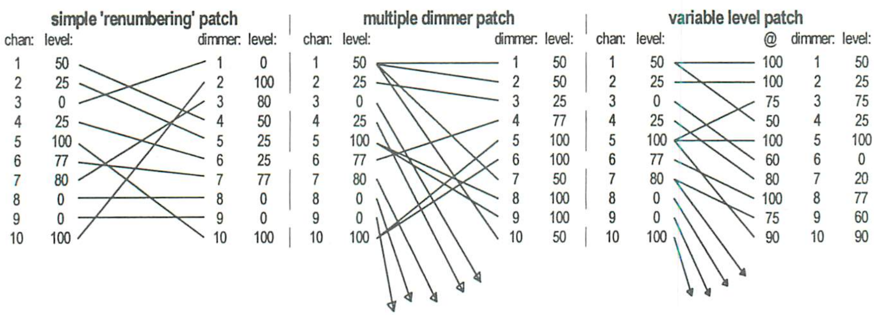


Patching and Merging Computers:

Patching Computers:

Patching computers are DMX512 devices that receive DMX, reorganise the channel numbers and then transmit the new 'patch'. When early DMX512 consoles first appeared such computers were the only way to obtain the function of the diode-matrix pin patch as used by analog systems. The patching function is now an integral part of most lighting consoles.

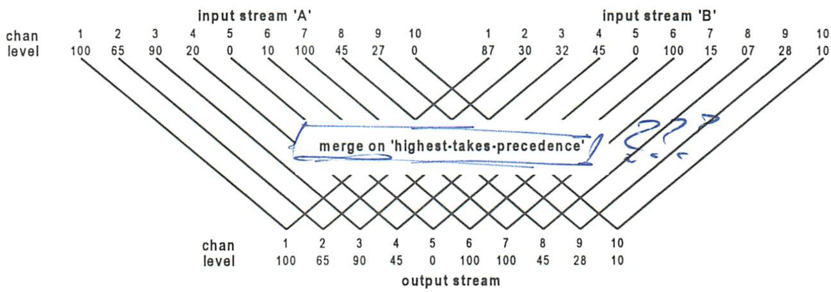
Patching allows one console channel to control any number of dimmers and in some cases for a dimmer to be controlled from a number of console channels on a highest-takes-precedence basis. Most patching systems also allow a dimmer to be patched at a known level. This means that the actual level sent to the dimmer can be scaled down, to increase lamp-life for instance.



In some patching computer systems the time taken to complete the patching process for each input-packet depends on the number of dimmers in the patch; the more there are the slower the update rate. This can lead to a curious fault where if a very small number of channels are patched the output packet-time is so short that some older equipment can malfunction. The solution is to patch a number of unused dimmers to a number of unused channels until the packet is slow enough to clear the fault. This phenomenon can also explain why sometimes a device will only work when connected through a patch but not if connected directly to a console.

Merging Computers:

Merging computers are less powerful than patching computers although they perform a similar function. They allow two separate DMX512 lines, emanating from different consoles, to be 'merged' into one composite signal. Although this is a less complex function than patching, it still requires a fast computer in order to read two simultaneous DMX512 inputs at full speed. Therefore merging devices may seem to be expensive for what appears to be a simple task.



A typical use for such a system is when moving lights are controlled from one type of desk and conventional dimmers from another. Merging computers simply merge the channels one-by-one from the two input streams, the higher value present on either stream being the one that prevails ('highest-takes-precedence').

Some merging computers allow the user to select an offset for the starting address of one of the inputs so that only partial overlap of channel numbers takes place. The channels on either input stream which do not overlap are passed through unaltered.

Merging computers can also be a convenient way of providing local control of dimmers for testing and work-light control or for emergency back-up, with a simple DMX512 console in addition to the main system console.

In-Line Backup Computers:

These are DMX512 devices that receive DMX, and in normal operation, pass the signal straight through. In the event of a failure of the main console, i.e. the absence of DMX512 for a certain period at the device's input, the back-up computer takes control of the output.

Simple back-up systems may just maintain the last set of levels from the main console so that there is a constant supply of DMX512 to the receiving devices, because some receiving devices do not like the absence of a signal for a long period.

More sophisticated systems exist which offer a number of pre-recorded lighting states controllable via faders which can either merge with, or take-over the console output to provide basic lighting control to run a show. Some of these devices perform this take-over function automatically.

Some digital dimmers and other devices may include integral merging (i.e. two or more DMX512 inputs), patching and back-up facilities.

Back-up computers decide that the console has failed if DMX512 is absent for a certain period of time. In the DMX512 spec. this time is 1 second. If a console is very busy, particularly if it is reading or writing a floppy disc, it may suspend DMX512 output for more than 1 second, in which case the back-up computer could take-over control. If a system with a back-up computer present in-line appears to freeze, with loss of console control when certain console operations are selected, it may be due to this auto-switching feature.

Processing delays:

Any computer which is in-line with the DMX512 signal from console to devices will introduce delays. The in-line device must decode and store the incoming DMX512 signal and then when it has performed its patching or merging function (which will also take some time) it can send the resulting levels on to the devices.

Different types of patching computers apply different rules as to when a new value at the input should be patched through to the output.

In the simplest scheme an input channel's value is stored in the computer's memory as soon as it arrives and the output function picks this value from the memory as soon as it is time to send that channel. This method can produce very little delay, but only if the input arrives just before the output is ready for that channel. If the input arrives just after the output 'slot' then the value has to be stored for nearly a complete packet time, until the next occurrence of that channel on the output. If a block of channels on the input changes simultaneously some of them might update their output on the current packet with the remainder updating on the next packet. This can lead to uneven fading and erratic chase behaviour.

The second method adopted is to accept only complete packets of data. Until a new packet has been completely assembled by the receiver function, the output function continues to use the previous packet's data. In practice a packet can be considered 'complete' when all the channels required by the device have arrived. This method overcomes the 'partial block update' effect described above but produces delays in the order of one output-packet time. The effect of this may still cause jerky operation but as all the channels change together it may be less noticeable when running chases.

Both these patching method yields delays from between 50μs approx. and the length of the output-packet.

With modern computers these delays should be in the order of 50 milliseconds (50ms) or less and will only be noticeable on fast chases or bump buttons (assuming that the console delays are negligible).

Most lighting operators start to perceive delays when they exceed approximately 150ms and often the DMX512 link will be blamed. Most of the delays will actually be due to the console and the receiving devices, but as long as they amount to less than 150ms they will not be noticeable. Thus a system can seem to slow down when a DMX512 link is introduced if this takes the combined delays above the 150ms threshold, even though the DMX512 link itself may only have contributed another 25-30ms of delay.

If many in-line devices are present, e.g. patching, merging and back-up computers, the accumulation of delays will become intolerable. The delays will show up as erratic chases, slow bump button response and fader 'stepping'. Only one or two such devices should normally be present in-line in order to minimise these effects.

There exists another class of in-line DMX512 computers which does not 'buffer' the whole DMX512 packet but just the most recent level. These devices synchronise their output to the input packet. When a new data value arrives this causes the previous channel to be transmitted, the delay is therefore equal to one frame-time of the input packet, or as little as 44µs. The problem with this method is that the break can only be detected after some of it, at least 38µs, has already elapsed and therefore the regenerated break may be shorter than the original, input-packet, break. Such devices are fairly uncommon as they require either complex hardware or very fast processing in order to compute the new output level within one frame-time. See also: Signal timings, page 51.

A certain amount of delay is inherent in the DMX512 protocol. All digital, serial communications will always be slower than parallel analog systems.

Analog Converters:

Analog conversion comes in two forms: Analog to DMX512 conversion and DMX512 to analog conversion.

Many older lighting devices still use 0-10 V, analog control signals. In addition, some modern devices use analog control signals because a built-in DMX512 decoder is too expensive.

Analog to DMX512 converters allow the use of simple consoles to control DMX512 equipment. In their basic form there are no controls, the unit simply sends its channels starting at channel one. More sophisticated A to D converters allow a number of such units to be connected together, each sends its channels 'joined onto' the end of the channels from the previous such unit. One of the units is set to be number one and controls the sending of the 'break' and the 'start-code'.

DMX512 to analog converters allow the control of simple 10 V devices from DMX512 consoles and other equipment. Such a converter is just like any other DMX512 receiving device. It will be fitted with a means to select which channel on the DMX512 link to respond to (or the starting address of a block of channels). The output will normally be 0 to +10 V d.c. at low current (typically several milliamperes). Some converters allow negative output voltage for devices requiring it.

Problems associated with conversion to and from analog control signals are:

- The output voltage is not a smooth continuum from 0 to full but a series of (up to) 256 steps. For a full-scale voltage of 10 V this yields a step size of about 40 millivolts (40mV). These steps are not noticeable on most devices but if an analog device, e.g. a colour scroller, is expecting say 5.0 V and it actually receives either 4.98 V or 5.02 V this could be the difference between two adjacent colour frames. This is a prime cause of colour scroll 'rattle' in combined analog/digital systems.

- The 40mV steps described above can also cause problems at the other end, analog to DMX, where a tiny fluctuation between two step values of the input will be converted into a larger fluctuation, of at least 40mV.
- These two phenomena, known as 'quantisation error', can cause quite large inaccuracies when signals are converted from analog to DMX512 and then back to analog.
- In addition to these effects, analog systems are prone to noise (often in the form of ground-loops) and drifting values due to temperature and component tolerances. These are some of the factors that led to the development of DMX512 in the first place !

Tips for users of analog converters:

- Use isolated DMX512 lines to keep grounds separate.
- Use short cables on the analog side.
- Avoid ground loops; either the converter should be grounded directly to the mains ground or through the analog cable shield *but not both !*
- Keep the converter equipment as far as possible from sources of interference, magnetic fields and heat.

0-10V Analog

10V / 256 Digital

40mV Schritte

Protocol Converters:

These are devices that accept DMX512 and convert the level information to another format, generally for use with an older product. Alternatively, these devices may accept the older protocol and convert this to DMX512. The most common conversions are to and from AMX192, an analog multiplexing scheme popular in the USA, or to and from D54, a similar analog multiplex developed by Strand Lighting in Europe. AMX192, as the name suggests, supports 192 channels, D54 supports 384 channels. Additional channels beyond either 192 or 384 respectively will be meaningless on the DMX512 side of the conversion, unless the protocol converter supports multiple units.

Both AMX192 and D54 are analog systems where the dimmer intensity is represented by a voltage. These two protocols can suffer from the same problems as parallel analog systems; hum, noise, drifting etc. The same precautions should be taken as detailed above for analog systems.

Address settings:

All DMX512 devices, except those that read all 512 channels, have a means to set the address, or addresses, that the devices' parameters will respond to. The most common method of addressing is the 'base address' where the address number selected is the first of a block of sequentially numbered channels which the device will accept. The user should verify the behaviour of channels patched to channels beyond 512. For instance a 48 channel dimmer rack set to base address 501 will have 36 channels 'in limbo', whilst some dimmer designs may 'wrap-around' these addresses back to channels 1-36.

Some devices allow a random addressing scheme where each channel within the device may be patched to any one of the DMX512 input channels

The following examples are of various base addressing schemes currently employed by different manufacturers. Remember that in all these examples the channel number refers to the DMX512 channel:

Digit display & keys:

These are the most straightforward interfaces to set-up as the choice of settings is restricted to valid addresses in the range 1-512. This type of interface also allows the same display to perform additional functions other than simply setting the base address.

Thumbwheel switches:

A popular, and very simple, user interface for address setting is a bank of three thumbwheel switches for setting the three digits of the desired base address, generally allowing settings from 0-999. The settings 0 and 513-999 may be used to set some other feature of the devices' operation; for instance, off-line and local test modes.

DIP switches:

DIP switches are banks of tiny individual switches which are either off or on. They are used to set the base address directly in binary code. These types of switches are difficult to interpret, as people do not 'think binary'. Additional difficulty comes from the different DIP switch implementations used by different devices.

A switch is a natural binary device. It is either off or on, therefore with one switch there are two possible states or numbers; 0 and 1. With 2 switches there are 4 possible states or numbers; 00, 01, 10, 11. With each extra switch there are twice the number of possible states.

One of the reasons that DMX512 has 512 channels is that this is a 'round' binary number. For 512 possible states (addresses) 9 switches are required:

Example DIP switch settings:

DIP switch setting weights									Binary code	DMX channel address
256	128	64	32	16	8	4	2	1		
- off	- off	- off	- off	- off	- off	- off	- off	- off	0	1
- off	- off	- off	- off	- off	- off	- off	- off	on -	1	2
- off	- off	- off	- off	- off	- off	on -	- off	on -	5	6
- off	- off	on -	on -	- off	- off	- off	on -	on -	99	100
on -	on -	on -	on -	on -	on -	on -	- off	- off	508	509
on -	on -	on -	on -	on -	on -	on -	on -	on -	511	512

Note that the numbers run from 0 to 511. Different devices interpret these switch numbers in one of two ways:

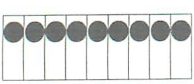
- In the first method the binary code 0-511 is equal to the desired channel address minus one, i.e. channel 1 is code 0 (all switches off), channel 100 is code 99 (001100011) and channel 512 is code 511 (111111111) etc. This is 'base-zero' numbering.

- In the second method the binary code 1-511 is the corresponding address 1-511, i.e. channel 1 is code 1, channel 100 is code 100 (001100100) and channel 511 is code 511 (111111111) etc. This is 'base-one' numbering. With this method channel address 512 is either unavailable or is selected by switch code 0, alternatively there may be a tenth switch just to select channel 512.

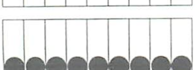
To confuse further this addressing scheme the switches are not always mounted the same way up. On some devices up will be 'on' whereas on others down will be 'on'. Also, some circuits use the switches with the polarity inverted, i.e. where a bit is '1' the switch is off. In the above three examples (base-zero) the settings would then be: chan. 1 (111111111), chan. 100 (110011100) and chan. 512 (000000000).

If the manufacturer's documentation is not clear on this point or not available, try operating DMX512 channel 1 (only) with the switches alternately all on and then all off. If the device responds with all the switches on, it has inverted switches. For this test make sure that the console patch, if present, is controlling <u>DMX512 channel</u> 1.

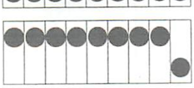
<u>Possible DIP switch settings for DMX512 channel 1</u>



Up is off, base-zero addressing.



Down is off, base-zero addressing.



Up is off, base-one addressing, switch # one is to the right.

Down is off, base-one addressing, switch # one is to the right.

Up is off, base-one addressing, switch # one is to the left.

Down is off, base-one addressing, switch # one is to the left.

The table on page 62 lists the DIP switch settings in DMX512 channel order, i.e. from 1-512 not 0-511, for base-zero addressing. If a device has base-one addressing, i.e. 1-511, add one to the desired address and then look up the binary switch code in the table.

If you find yourself needing to read a DIP switch setting without the benefit of the table in this booklet, remember that the base address for a given setting is the sum of the bit weights for the 'on' DIP switches (for 'base-one' addressing), or the same sum plus one (for 'base-zero' addressing).

Here are some examples (base-zero addressing):

DIP switch setting weights									DMX512
256	128	64	32	16	8	4	2	1	base address
on	-	on	-	on	-	on	-	on	256
-	off	-	off	-	off	-	off	-	64
									16
									4
									1
									+ 1
									342
-	-	-	on	on	on	-	-	-	32
off	off	off	-	-	-	off	off	off	16
									8
									+ 1
									57
-	on	-	-	-	-	on	on	-	128
off	-	off	off	off	off	-	-	off	4
									2
									+ 1
									135

Address offsets for multiple DMX512 lines:

When a system comprises more than 512 receiving device channels, additional DMX512 lines are employed. Thus a console with 1024 output channels will be fitted with two DMX512 output ports, one with 1536 output channels will be fitted with three DMX512 output ports, and so on.

Each of these 512 channel ports are also known as 'DMX universes' each with 1-512 channels. Receivers, however, in most cases have only one input port, with addressing selectable in the range 1-512. In order to set a device to respond to, say, console output channel 1200 it is necessary to connect to console port 3 and set the address to 1200-512-512 = 176, universe 3.

The table on page 67 lists the relation between sequentially numbered DMX512 channels, as they would appear on the console, and universe numbered channels in blocks of 512, as they would appear on a receiving device.

These tables assume that each port on a multi-port console outputs a full 512 channels.

For instance, if a system comprises two 480 way dimming systems, each with one DMX512 input, it is not possible to patch the second system to console output channels 481-960 since these straddle the two outputs. The solution is to connect the second system to the second DMX universe from the console and then patch it to channels 513-992. This leaves channels 481-512 unpatched.

Some consoles allow the user to define the number of channels on a DMX512 output port in order to match this to the number of devices and thus to achieve a continuously numbered patch without any gaps.

Fault Finding:

DMX512 faults can be quite difficult to analyse, mostly due to the system's relatively high speed. It is notoriously hard to trigger an oscilloscope from the DMX512 line and to be sure of what is being observed. There are, however, some simple tests that can be carried out with a basic multimeter which will show up many common problems.

The results of these tests will depend on the type of console, the type of multimeter and the termination resistance value. It is a good idea to make these measurements on your system when it is fully working and then to keep a note of the readings and the type of instrument used to make them. If there is a fault in the future it may be possible to identify the problem by simple comparison of the readings. The same type of multimeter should be used as for the original tests.

Voltage Tests:

With the console and all the devices connected together measure the d.c. voltages between pins 2 and 3 (multimeter negative to pin 2) under the following conditions:

All DMX512 channels at zero (off); the meter should read low or negative voltage

All DMX512 channels at full; the voltage should increase but it may still be negative if the break is very long and there are few channels on the link.

Although the measurements have no *absolute* meaning there should be a noticeable change of voltage. Make sure that all channels are set to either full or off, i.e. that there is no partial patch in the console causing only some DMX512 output channels to be affected.

For this test an analog, moving coil, meter may give more consistent readings as it will naturally average the digital data signals. Some digital meters may give unpredictable and unrepeatable readings. A good place to take the measurements is across the terminator resistor, particularly if this is the 'dummy plug' type.

Repeat the readings for pins 1 to 2 and pins 1 to 3 (multimeter negative to pin 1) and make a note of the 'normal' values. The pin 1 - 3 readings should behave like the first test, i.e. an increase in level corresponds to an increase in voltage. The pin 1 - 2 test will be inverted, i.e. an increase in level should produce a decrease in voltage

Common-mode voltage tests:

These tests will determine if a common-mode voltage problem exists between the DMX512 network and a receiving device. Set the voltmeter to d.c. and disconnect the receiver from the line. Measure the voltage between the line pin 1 and the receiver pin 1. If the reading is 7 V or greater there is an unacceptable common-mode voltage. Repeat the readings with the meter set to read a.c. volts. A reading of approx. 5 V or more also indicates excess common-mode voltage. Unless it is possible to re-arrange the grounding to eliminate the voltage it will be necessary to use an opto-isolated repeater/splitter between the network and any devices exhibiting the above problem. Note that this may be necessary in a number of different parts of the network as receivers may suffer common-mode voltage not only with the console but also between themselves.

As common-mode voltage is influenced by the amount of current flowing in the entire power system these measurements should be carried out with the system running a typical variety of heavily loaded dimmers. Some experimentation may be required in order to find the worst-case common-mode voltages.

Resistance tests:

With the transmitter disconnected and all the receivers connected, measure across the console-end male connector:

Test	Normal value	Abnormal value	Possible faults
pin 1 - pin 2	Greater than 2k ohms	Open circuit	Either no devices, only current mode devices or broken wire.
		Less than 200 ohms approx.	Faulty receiver, short circuit in line or connector wiring error.
pin 1 - pin 3	Greater than 2k ohms	Open circuit	Either no devices, current mode devices only or broken wire.
		Less than 200 ohms approx.	Faulty receiver, short circuit in line or connector wiring error.
pin 2 - pin 3	90 - 120 ohms approx.	400 - 20k ohms approx.	Missing or incorrect termination.
		Open circuit	Broken wire or faulty receiver(s).
		Less than 75 ohms approx.	Multiple terminators on line, short circuit in line.
Connector shell to any pin	Open circuit	Less than several Mega-ohms	Short circuit to connector body or excessive moisture inside connector.

Oscilloscope tests:

There are a number of items of DMX512 test equipment which enable an oscilloscope to be used to view the DMX512 signals. If a 'scope can be reliably triggered to show a part of the DMX512 waveform it may be possible to identify the cause of a fault or to identify which equipment does not fully adhere to the DMX512 specification. The aspects of the signal which should be measured are: min. and max. break length, Mark-after-break length, data gap time and idle time after the last channel. Without a trigger detector it will be very difficult, if not impossible, to synchronise the 'scope to the DMX512 packet, and therefore these timing readings should be treated with caution. (see page 51 for signal timing details)

An oscilloscope can still be useful, even without a DMX512 trigger detector, for examining the quality of the signal and the effects of termination. Things to look for are: high frequency noise, low frequency noise (superimposed mains, 50 or 60Hz), distortion of the square edges of the signal and insufficient voltage at the far end of cable. Signal reflections will be more difficult to observe unless the 'scope has a very stable trigger.

Specialised DMX512 test equipment:

There is a wide variety of DMX512 test equipment now available which can be used to analyse DMX512 signals, identify faults and generate reference signals. Such instruments can:

- Display a range of levels,
- Flash dimmers for testing
- Display input timings and variations
- Adjust output timings
- Trigger logic analysers and oscilloscopes
- Modify or filter start-codes
- Generate reference DMX512 packets at the fastest rates

Manufacturers and system designers should make the maximum use of this equipment in order to ensure that their products conform within *all* the limits of the DMX512 (1990) specification.

Fault Finding Checklist:

Most DMX512 faults are due to incorrect termination, faulty wiring or ground-loop effects. Before embarking on a complex set of tests always check these simple things:

- Are there too many devices on the line?. This could be the case if some of them are DOL isolating receivers, otherwise up to 32 standard EIA485 receivers are allowed.
- Is the line terminated, once only at the far-end, with approximately 120 ohms?
- Are all the conductors connected at both ends of the cable? DMX512 has an annoying tendency to work intermittently even if the inverted-data wire is cut (pin 2).
- Is one of the data signals missing? This may cause random flickering in addition to apparent normal operation.
- Does the introduction of an opto-isolator in the network clear-up or reduce the problem? If so, there is probably a ground-loop effect. It may be possible to re-route the power cabling in such a way as to minimise this effect. Otherwise, it may be necessary to introduce opto-isolation to some branches of, or all of, the DMX512 network.

The EIA485 (RS485) communications spec.:

DMX512 is designed to connect with cables via an industry standard interface called EIA485 (commonly referred to as RS485). EIA485 is only a description of the electrical level of the interface, the voltages, currents and i.c. devices. It would be possible to connect a DMX512 device to another EIA485 device, e.g. a computer or machine, with no damage. However, the signals would be meaningless, except to another DMX512 device.

EIA485 specifies that the connection between transmitter and receiver is achieved with two or three wires: a data wire, an inverted data wire and, often, a ground/return/0V wire. The two data wires are twisted together and enclosed in a metal shield formed by the 0V wire. This helps to eliminate magnetic hum pick-up and interference.

Data is sent as a series of high and low levels on the line. The line is considered high when the data wire is positive with respect to the inverted data wire. The line is considered low when the data wire is negative with respect to the inverted data wire. In some systems the 0V wire is only required as a shield and is not connected to the receiver circuitry (see page 19, Network Isolation).

This method of sending the signal on one wire and sending the opposite, or complement, signal on another wire is known as 'balanced' transmission. The receiver detects the difference between the data wire and the inverted data wire in order to decode the signal. Any interference picked up by the cable will almost certainly affect both data wires equally and will therefore be ignored by the receiver.

The wires are twisted together in order to ensure that any extraneous signals are picked-up by both data wires. This twisting is the most important measure to reduce interference and is more effective than the cable shield. For this reason it is not recommended to use a normal twin shielded cable as many of these cables, e.g. for audio or general use, do not have the conductors twisted together.

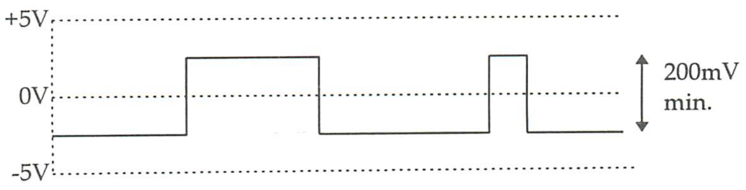
EIA485 voltages:

EIA485 states that the receiver should detect a difference between the two data wires of as little as 200 millivolts (0.2V / 200mV) which allows the receiver to function correctly even if there are large volt drops down the cable.

Note that DOL opto-isolators cannot possibly meet this requirement. The LED within the isolator will typically require at least 1 V in order to operate, this is another reason why the use of DOL devices may cause problems and is not recommended.

Typical voltages found on a EIA485 cable:

(measured across the terminator resistor)



EIA485 will also tolerate both data wires having a common voltage imposed upon them, relative to the ground / 0V wire. This is known as the 'common mode voltage range'. The allowable limits of common mode voltage are +12 to -7V. This means that the ground / 0V point of the transmitter and receiver need not necessarily be connected directly together providing that the voltage difference between them is less than +12V and more than -7V at all times.

Auf 0V bezogen

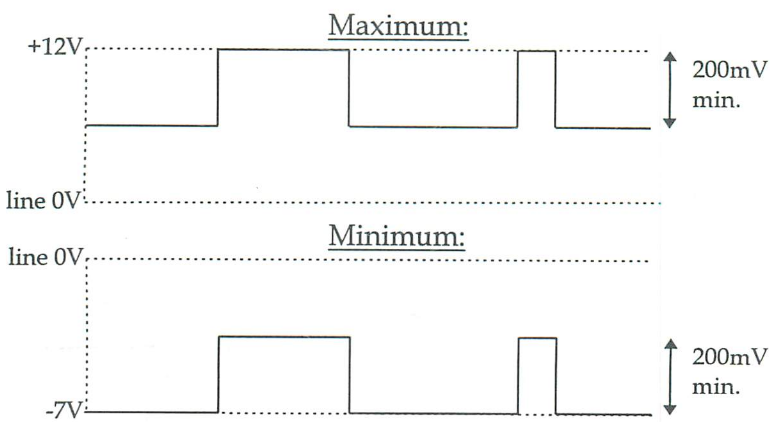
Min. & Max. voltages with respect to ground / 0V (at the receiver):

	Minimum		Maximum	
logic level:	Data +	Data -	Data +	Data -
0	-7V	-6.8V	+11.8V	+12V
1	-6.8V	-7V	+12V	+11.8V

Note that it is *not* allowed to hold one line at, say, 2.5V and toggle the other between 0 and +5V. EIA485 states that the common mode voltage of the transmitter must not change by more than 200mV between logic states.

<u>Allowable extremes for EIA485 voltages:</u>

(measured from either data wire to shield wire, pin 1)



Important: If common-mode voltage exceeds these limits, damage may be caused to both the transmitter and receiver circuits.

Bits & Bytes:

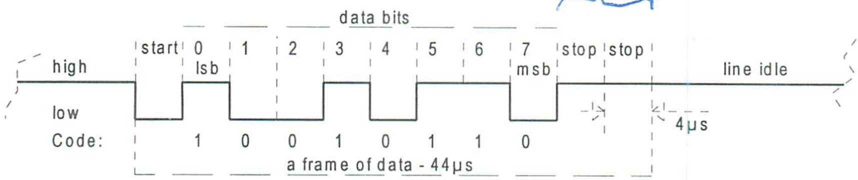
EIA485 (RS485) describes the *physical* level but not the meaning of the signals. DMX512 describes the signals in fair detail but still with some room to manoeuvre. This flexibility allows for different design solutions to meet different needs and budgets. For instance, DMX512 is not limited to exactly 512 channels, as the name suggests. If fewer channels are sufficient, the standard permits the use of a lower last-channel number.

The basic element of any communications protocol is a set of codes. Each code is a unique series of high and low signals on the line, called *bits*. The bits are sent out at predetermined time intervals which for DMX512 is every 4 microseconds (4µs). In DMX512 each code is 8 bits long and is called a *byte*. The 8 bits in a byte allow 256 different bit combinations or codes which allows the choice of 256 levels - from 0 to full (255). See page 72 for code conversion table.

In addition to the bits in a byte it is necessary to mark where the byte begins and ends so that the receiver can synchronise with the signal. For this purpose there are three more bits added to the byte. They are a start bit (low) and two stop bits (high).

When the line is not sending any information it rests or 'idles' in the high state. When a byte is sent the start bit instructs the receiver to start reading the remaining bits at 4µs intervals until 8 bits have been read. The receiver then expects the line to go high for two bit periods for the stop bits. At the end of the second stop bit the line can either idle, (it is already high so this means do nothing) or a new start bit can initiate another byte transfer.

Thus there are 11 bits in total for each byte that is sent, 4µs x 11 = 44µs per byte. These 11 bit codes are called 'frames'.



If the line were to transmit these bits continuously (i.e. with no idle gap between frames), the 4µs interval would allow 250,000 bits per second to be sent. This is the 'speed' of DMX512, known as the baud rate. The baud rate for DMX512 is usually stated as 250k baud.

However, DMX512 is an asynchronous protocol. This means that the frames can be sent at any time that the line is idle. In practice most lighting consoles, either regularly or occasionally, insert idle gaps between frames. Typically, consoles insert idle gaps because they are too busy performing some computation to get the next frame out as soon as the current one has finished being sent.

The DMX512 packet:

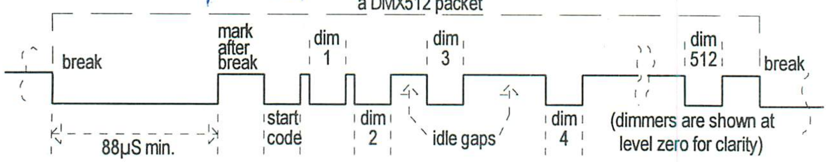
DMX512 supports up to 512 channels of data which are sent out sequentially from channel 1 to the highest numbered channel available from the console. Although technically possible, the DMX512 standard does not allow for more than 512 channels to be transmitted on the link. Some types of analogue to DMX converters may be chained together until the number of transmitted channels exceeds 512.

The use of more than 512 channels on a DMX512 link is not part of the USITT standard and may cause problems with some receiving devices.

Consoles providing more than 512 dimmer outputs are fitted with two or more DMX512 outlets (see page 67). DMX512 channels should not be confused with console channels or dimmer channels. When patching is present a console channel could affect several DMX512 channels, or none. DMX512 channels could then in turn be patched (in the dimmer or an in-line patching computer) to several dimmers, or none.

In order that the receiver can identify which is channel 1, the line is set to a special condition known as 'break' (Remember that all 256 possible codes are used for level information). The break condition is a continuous low signal on the line for at least 88µs (two complete frames, i.e. two bytes each including start & stop bits). This signals to the receiver that the following information is the start of a new 'packet' of data levels.

At the end of the break period the line is taken high for a short period of time known as the Mark-after-break or m.a.b. time, (see Signal Timing section, page 51). Following the m.a.b. a special code is sent. The DMX512 standard calls the first byte after the break the 'start-code' and this name is used throughout this booklet. For dimmer level data this byte is value zero. A start-code of zero indicates that the following bytes are 8 bit dimmer levels. Non-standard terms for this code are the mode byte, type code, header byte or packet header.



The other 255 different possible start-codes are not defined by DMX512, although some have been reserved. Some manufacturers use non-zero start-codes to send additional information unique to their products. Future enhancements to the DMX512 specification will use alternative start-codes, for instance for error checking and 'talkback' or to send data other than levels. Compatibility is ensured, however, as start-code zero will always indicate 8 bit level information.

Since DMX512 was first developed for controlling dimmers it has also been adopted by moving light and colour-changer instruments. Although these are not strictly dimmers, it is very convenient to use a standard console to control these devices.

All current DMX512 devices work with start-code zero. However, not all current devices actually check the start-code. In some simpler designs the start-code is simply discarded and assumed to be zero.

Devices which do not check the start-code will have problems with consoles that send any other start-codes. Furthermore, such devices are unlikely to remain compatible with future revisions of the DMX512 standard.

Refresh rate:

The refresh rate is the number of packets sent per second. Because DMX512 allows gaps between frames and only specifies the *minimum* break time the refresh rate can be very different between different makes of console. The maximum possible refresh rate also depends on the number of channels being sent.

In the case of 512 channels the time to send one packet is:

Name:	Number:	Time:	Total time:
Break	1	88µs	88µs
Mark-after-break	1	* 8µs	8µs
Start-code	1	44µs	44µs
Data bytes	512	44µs	22,528µs
TOTAL			**22,668µs**

* This was allowed to be as short as 4µs in the original DMX512 standard of 1986, the revised DMX512(1990) standard specifies 8µs minimum m.a.b. time.

This yields a refresh rate of 44.115Hz. This is the number of packets sent per second but it does not necessarily mean that each packet contains new levels, because if the console is slow at calculating fades it may the send the same level on several consecutive packets.

In theory, packets could exist with just one channel. With the above timings, such packets would be 184µs long with a refresh rate of 5.434kHz. This is the fastest rate possible and may be produced by DMX testing equipment. The fastest rate from a typical 24 channel console would be obtained with packets 1196µs long, giving 836Hz.

Minimum length DMX512 packet:

Name:	Number:	Time:	Total time:
Break	1	88µs	88µs
Mark-after-break	1	8µs	8µs
Start-code	1	44µs	44µs
Data bytes	24	44µs	1,056µs
TOTAL			**1,196µs**

This figure, 1196µs, is the *required* minimum packet length.

This timing was added as a requirement in the 1990 revision of the DMX512 standard. In practice smaller consoles generally stretch the packet with longer data gap timing and/or extended break/idle/m.a.b. timings (see page 51).

Although the 1196µs required minimum packet time corresponds to 24 channels at the maximum possible rate, there is no limit on the minimum number of channels. For instance, a 6 channel packet is perfectly valid providing that enough idle time is inserted between frames in order to extend the packet time to at least 1196µs.

When a packet is stretched in this way in order to deliberately reduce the refresh rate it should be accomplished by extending the mark or idle period, *not* the break time. The mark period can be extended at the Mark-after-break, between data frames or after the last channel before the start of the next break.

Signal timings:

Some consoles, and other DMX512 transmitters, allow the user to set up the output timing, or to choose from a number of different timing 'flavours'. This can be useful when there are devices connected which are not fully compliant with the DMX512 specification and are unable to receive DMX512 at the maximum possible speed. This has been a problem with early designs of dimmers, moving lights and colour scroll changers.

Where problems exist it is often due to inadequate testing of the device for all the valid range of DMX512 timings. In the early days of DMX512 there were few, if any, consoles capable of transmitting DMX512 at the maximum possible rate and so receivers built then may have functioned perfectly well. With the availability of fast microprocessors most modern designs can transmit at, or near to, the maximum possible rate and so the user can experience problems with older devices.

It is natural for the user to assume that problems experienced when a new console fails to control a system properly are due to the new console. This is rarely the case.

It should be emphasised that a truly compliant DMX512 design should work with any other DMX512 equipment. Indeed this is crucial test of a 'standard'.

What follows is some advice on how to best set the timings for these 'rogue' devices.

Break timing:

The break length time is critical for certain devices. Although DMX512 does not specify a maximum length for break, some devices are sensitive to the break length and can malfunction if the break is too long. A break length of 100μs to 200μs will overcome these problems.

Some devices measure the break length with a timing circuit to see if it exceeds 88μs. If the transmitter is sending a break of exactly 88μs, due to tolerances the receiver may decide that it is longer or shorter than 88μs. When the receiver decides that the break is longer than, or equal to 88μs, the packet will be accepted as a valid packet. When the receiver decides that the break is less than 88μs the packet will be discarded. Therefore transmitters should always be set to produce a break *longer* than 88μs, e.g. 100μs.

In addition, some other devices actually detect a break of as little as 38μs. This is because the *UART* circuits in these devices detect byte code 0 with a missing stop bit and interpret this as break. However, this should not be a problem as all DMX512 compliant transmitters generate two stop bits.

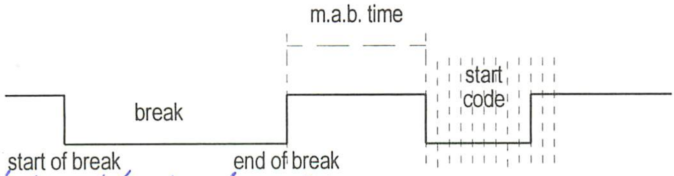
A DMX512 compliant device should be able to detect a break of 88μs or greater.

Mark-after-break timing:

The Mark-after-break time as specified in DMX512 has been a source of difficulties for designers of DMX512 equipment. The original specification was 4μs min. m.a.b. time. For slower receivers this was not enough time to recover from the break and then catch the first byte (the start-code). In this case they would probably catch the second byte instead (dimmer 1) and treat it as the start-code. If dimmer 1 was at value 0 the receiver would use this as the start-code for dimmer levels and then read in the following values, all offset by one from their true channel number. As this phenomenon was erratic the dimmer signals would appear to shuffle up and down between adjacent channels. If this effect is seen and it is possible to alter the m.a.b. time of the transmitter, it should be set to around 44μs.

The current DMX512 (1990) spec. has changed m.a.b. time to 8μs minimum which largely clears up this problem.

Any device which is DMX512 (1990) compliant should be able to detect a Mark-after-break of 8µs or greater.

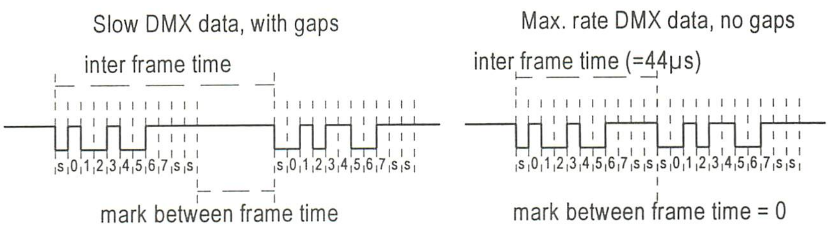


Inter-frame time / Mark-between-frame time:

The Inter-frame time is the time between the start of one frame (11 bits) and the next, and its minimum possible length is 44µs.

The Mark-between-frame time is the amount of time (if any) between the end of one frame (end of the 2nd stop bit) and the start of the next (start of the start bit), and its minimum possible length is 0.

The maximum possible Mark-between-frame time is one second, after which the signal is considered to have failed.



Most consoles send data at somewhat less than the maximum possible rate, particularly if they are performing a complex computation at the time. However some consoles are able to do this, either continuously or in short bursts. This can cause problems in some receivers.

If a device is unable to keep up with the signal it may occasionally drop a channel, with all subsequent channels shifted down by one. This could happen several times during the course of a packet, resulting in quite large shifts for higher numbered channels.

If this effect is seen and the Inter-frame time can be adjusted, try setting it between 55µs and 60µs. This solves most such problems without affecting the refresh rate too severely. An Inter-frame time of 60µs with 512 channels per packet produces a refresh rate of approximately 32Hz.

<u>Break-to-break time:</u>

This is another term used to describe the refresh rate as the time between the start of one packet to the start of the next. The refresh rate, in Hertz, is the reciprocal of the Break-to-break time, i.e.

$$\frac{1}{t(break-to-break)} = Rate(Hz)$$

The minimum Break-to-break time is the required minimum packet time of 1196µs. The maximum Break-to-break time is 1 second.

<u>Loss of data tolerance:</u>

The DMX512 specification requires that devices retain their most recently received levels for one second in the event of loss of data.

The specification <u>*does not*</u> define what will then happen afterwards. Some devices may retain the levels indefinitely, some may immediately set levels to zero and others may feature a 'safe state' facility to substitute the last levels for a preset lighting state. Additionally, some devices allow the user to program the time allocated for fading to the safe or blackout state in the event of loss of the DMX512 signal.

There are a few dimmer designs which rely on the refresh rate of the DMX512 packet in order to refresh internal circuitry. These devices may exhibit erratic behaviour when no DMX512 signal is present for a long period. Some of these dimmer designs may eventually drift up to full-on. In such cases care should be taken to power-up dimmers after establishing DMX512, and then to power-down before disabling DMX512.

Summary of DMX512 packet timings:

The following are the limits of the DMX512 specification for the different parts of the DMX512 packet:

	Min.	Max.	Units
Break	88	(note 1)	µs
Mark-after-break time	8 (note 2)	(note 1)	µs
Inter-frame time	44	(note 1)	µs
Mark-between-frame time	0	(note 1)	µs
Mark-after-last-channel (before break)	8 (note 3)	(note 1)	µs
Refresh time (24 chans)	1,196	(note 1)	µs
Refresh time (512 chans)	22,668	(note 1)	µs
Refresh rate (24 chans)	1	836	Hz
Refresh rate (512 chans)	1	44	Hz

Notes:

(1) Any time up to a total of 1 second for a complete packet

(2) 4µs for original DMX512 spec (1986)
8µs for current DMX512 (1990) spec.

(3) 8µs for the two stop bits of the last frame (highest numbered channel). The break can start immediately after the end of the second stop bit.

Glossary of terms:

A to D	Analog to digital conversion.
Amplifier, distribution	See repeater
Analog	A continuous range of values or voltages with no steps in between.
Asynchronous	Signals that start at any time and are not locked or synchronised to the receiving device by a separate clock line.
Back-up	A computer system to provide DMX512 signals in the event of a console failure.
Balanced line	A data communications line where two wires are present, the signal and its opposite (or complement), the actual signal being the difference between the two voltages on these wires. Balanced lines have excellent noise and interference rejection properties.
Base address	The address to which the lowest numbered channel in a device will respond. Subsequent channels in the same device will respond to subsequent channels on the DMX512 link.
Baud rate	The number of bits per second. For DMX512 this is 250,000 (250k baud).
Bit	The smallest piece of information used by computers, a bit is either low or high, true or false, zero or one.
Break	A continuous low on the DMX512 line for 88μs or more indicating the start of a new packet of information. This signal is also sometimes known as RESET.
Byte	8 bits.

Characteristic impedance	The impedance of a cable supposing it had infinite length. It is equal to the value of the terminator resistor that should be used. The characteristic impedance should not be confused with the cable's d.c. resistance.
Common-mode voltage	The voltage difference between the various ground points of the DMX512 network.
Console	A lighting control desk or any other equipment that produces DMX512 signals.
Converters	Equipment to convert DMX512 to or from analog control signals.
Current-mode receivers	Receiver circuitry which senses a current flowing between the data and inverted data wires instead of sensing the voltage difference. *Such receivers are not EIA485 compliant and may cause problems in DMX512 networks*.
D to A	Digital to Analog conversion.
DOL	See direct-on-line
Data	Information coming from or going to a computer.
Data link	An alternative name for the DMX512 line.
Data rate	The rate at which serial information is sent. If there are no idle gaps between frames the data rate is equal to the baud rate (250,000 for DMX512).
Device	A DMX512 receiver.
Direct-on-line	An optical circuit connected directly to the line for safety isolation, see Current-mode receivers.
DMX	Acronym for 'Digital Multiplex'
DMX512	The original DMX512 spec. by USITT (1986).
DMX512(1990)	The updated DMX512 spec. of 1990.
DMX twofer	See 'Y' cord. *Do not use these as DMX512 adapters.*
Driver	The circuit which drives the transmit signal and is directly connected to the DMX512 line.

Earth	See ground
EIA	Electronics Industries Association
EIA485	The specification of the electrical interface used by DMX512 to connect to the line. More commonly known as RS485.
FEP	Fluorinated Ethylene Propylene. A cable insulation which is rated up to 150-200°C operation.
Frame	A set of 11 bits of data, 1 start bit, 8 data bits (the level or start-code byte) and 2 stop bits.
Ground	The safety electrical connection to earth or to surrounding exposed metalwork. *The ground connection should not be removed from a console or receiving device as this may render the equipment unsafe and illegal.*
Ground loop	A connection between two earth / ground points at differing potentials thus causing a current to flow. The magnitude of this current may cause errors or, exceptionally, damage to equipment.
Highest-takes-precedence	A rule for deciding that a channel is controlled by the highest value when a number of controllers are attempting to set a level.
HTP	See highest-takes-precedence.
Idle	The time that the DMX512 line is idle (high) and not sending any information. Also known as the 'mark' condition.
Isolation	The provision of electrical isolation between different parts of a system for safety and noise rejection.
Isolation voltage	The voltage which can be safely sustained between separate, isolated parts of a system. *A high isolation voltage does not guarantee complete immunity from damage if high, i.e. mains, voltage is allowed on to the DMX512 line.*
Last action	See latest-takes-precedence

Latest-takes-precedence	A rule for deciding that a channel is controlled by the most recently selected action, e.g. button press, fader etc.
LED	Light emitting diode
Line	The cable carrying the DMX512 signals.
LSB	Least significant bit; the bit in a binary value which carries the least weight, this is bit 0, weight 1.
LTP	See latest-takes-precedence
M.a.b.	See Mark-after-break
Mark-after-break	The idle time between the end of the break and the start of the start-code.
Merge	A method of combining two separate streams of DMX512 information together, with highest-takes-precedence.
Mode byte	See start-code
MSB	Most significant bit; the bit in a binary value which carries the most weight, for a byte this is bit 7, weight 128.
Opto isolator	A circuit using optical techniques to isolate the electrical connections between a console and a device.
Packet	A complete set of data for a DMX512 transmission; break, start-code and data levels.
Packet header	See start-code.
Patching	The routing of console channels to DMX512 channels and/or DMX512 channels to dimmer channels.
Pile-on	See highest takes precedence.
PLASA	Acronym for the Professional Lighting And Sound Association.
Plenum	The air return path of a central air handling system, either ductwork or open space over a suspended ceiling.

Plenum cable	Cable approved by the Underwriters Laboratory for installation in plenums without the need for conduit.
Poly-urethane	Cable jacket compound with good abrasion and solvent resistance for use in harsh environments.
PTFE	Poly-tetra-fluoroethelyne, a high temperature plastic for cable insulation. PTFE is extremely stable and inert up to 200°C but will produce highly poisonous products at higher temperatures or when burnt.
PVC	Poly-vinyl-chloride. The most common cable insulation plastic, rated for 60 - 105°C operation.
Quantisation	A form of distortion of the original analog signal as it is converted to the nearest digital value.
Reflections	Spurious signals on the DMX512 line caused by incorrect termination.
Refresh rate	The number of DMX512 packets sent per second.
Repeater	An amplifier to extend cable length or to increase the number of devices on one line.
Reset	See Break
RS485	The generic specification for the cable and electrical medium used by DMX. Now known as EIA485
Shield	The outermost conductor of a cable inside which the signal conductors are enclosed. Also known as the screen.
Splitter	A repeater amplifier with a number of independent outputs.
Start bit	The extra bit attached to the beginning of a byte to indicate to the receiver that a new byte is being sent. The start bit is always low, i.e. value zero.

Start-code	The first byte sent after break, indicating the type of information to follow, start-code = 0 for dimmer levels.
Stop bit	The extra bit(s) attached to a byte to indicate the end of the byte, DMX512 has two stop bits. The stop bit is always high, i.e. value one.
Synchronous	Signals that are locked to a master clock pulse.
Terminator	A 100-120 ohm resistor fitted to the end of a DMX512 line furthest from the transmitter (across pins 2 & 3).
Twisted pair	A type of cable where the inner conductors are twisted together in order to reject interference in balanced-line systems such as EIA485.
UART	Universal Asynchronous Receiver Transmitter. The circuit which decodes serial data into byte values, and may also handle break detection.
Unit load	Unit load is an electrical specification defined by EIA485. Most receiver circuits present a unit load of between 0.6 and 1
Update rate	Same as refresh rate.
USITT	U.S. Institute of Theatre Technology.
XLR	The trademark of ITT Cannon, also used as a generic term to describe connectors by Switchcraft, Neutrik, Deltron, and others.
Y cord	A cable connecting one transmitter to two receivers. Also known as a 'DMX512 twofer' *Such cables will cause problems with DMX.*

DIP switch codes:

These DIP switch settings are shown with the 0-511 binary codes corresponding to channels 1-512. If the device has inverted switches, set a 1 in place of a zero and vice-versa., i.e. for channel 51 with inverted switches set: 111001101

256	128	64	32	16	8	4	2	1	Addr
0	0	0	0	0	0	0	0	0	1
0	0	0	0	0	0	0	0	1	2
0	0	0	0	0	0	0	1	0	3
0	0	0	0	0	0	0	1	1	4
0	0	0	0	0	0	1	0	0	5
0	0	0	0	0	0	1	0	1	6
0	0	0	0	0	0	1	1	0	7
0	0	0	0	0	0	1	1	1	8
0	0	0	0	0	1	0	0	0	9
0	0	0	0	0	1	0	0	1	10
0	0	0	0	0	1	0	1	0	11
0	0	0	0	0	1	0	1	1	12
0	0	0	0	0	1	1	0	0	13
0	0	0	0	0	1	1	0	1	14
0	0	0	0	0	1	1	1	0	15
0	0	0	0	0	1	1	1	1	16
0	0	0	0	1	0	0	0	0	17
0	0	0	0	1	0	0	0	1	18
0	0	0	0	1	0	0	1	0	19
0	0	0	0	1	0	0	1	1	20
0	0	0	0	1	0	1	0	0	21
0	0	0	0	1	0	1	0	1	22
0	0	0	0	1	0	1	1	0	23
0	0	0	0	1	0	1	1	1	24
0	0	0	0	1	1	0	0	0	25
0	0	0	0	1	1	0	0	1	26
0	0	0	0	1	1	0	1	0	27
0	0	0	0	1	1	0	1	1	28
0	0	0	0	1	1	1	0	0	29
0	0	0	0	1	1	1	0	1	30
0	0	0	0	1	1	1	1	0	31
0	0	0	0	1	1	1	1	1	32
0	0	0	1	0	0	0	0	0	33
0	0	0	1	0	0	0	0	1	34
0	0	0	1	0	0	0	1	0	35
0	0	0	1	0	0	0	1	1	36
0	0	0	1	0	0	1	0	0	37
0	0	0	1	0	0	1	0	1	38
0	0	0	1	0	0	1	1	0	39
0	0	0	1	0	0	1	1	1	40
0	0	0	1	0	1	0	0	0	41
0	0	0	1	0	1	0	0	1	42
0	0	0	1	0	1	0	1	0	43
0	0	0	1	0	1	0	1	1	44
0	0	0	1	0	1	1	0	0	45
0	0	0	1	0	1	1	0	1	46
0	0	0	1	0	1	1	1	0	47
0	0	0	1	0	1	1	1	1	48
0	0	0	1	1	0	0	0	0	49
0	0	0	1	1	0	0	0	1	50
0	0	0	1	1	0	0	1	0	51
0	0	0	1	1	0	0	1	1	52
0	0	0	1	1	0	1	0	0	53
0	0	0	1	1	0	1	0	1	54
0	0	0	1	1	0	1	1	0	55
0	0	0	1	1	0	1	1	1	56
0	0	0	1	1	1	0	0	0	57
0	0	0	1	1	1	0	0	1	58
0	0	0	1	1	1	0	1	0	59
0	0	0	1	1	1	0	1	1	60
0	0	0	1	1	1	1	0	0	61
0	0	0	1	1	1	1	0	1	62
0	0	0	1	1	1	1	1	0	63
0	0	0	1	1	1	1	1	1	64
0	0	1	0	0	0	0	0	0	65
0	0	1	0	0	0	0	0	1	66
0	0	1	0	0	0	0	1	0	67
0	0	1	0	0	0	0	1	1	68
0	0	1	0	0	0	1	0	0	69
0	0	1	0	0	0	1	0	1	70
0	0	1	0	0	0	1	1	0	71
0	0	1	0	0	0	1	1	1	72
0	0	1	0	0	1	0	0	0	73
0	0	1	0	0	1	0	0	1	74
0	0	1	0	0	1	0	1	0	75
0	0	1	0	0	1	0	1	1	76
0	0	1	0	0	1	1	0	0	77
0	0	1	0	0	1	1	0	1	78
0	0	1	0	0	1	1	1	0	79
0	0	1	0	0	1	1	1	1	80
0	0	1	0	1	0	0	0	0	81
0	0	1	0	1	0	0	0	1	82
0	0	1	0	1	0	0	1	0	83
0	0	1	0	1	0	0	1	1	84
0	0	1	0	1	0	1	0	0	85
0	0	1	0	1	0	1	0	1	86
0	0	1	0	1	0	1	1	0	87
0	0	1	0	1	0	1	1	1	88
0	0	1	0	1	1	0	0	0	89
0	0	1	0	1	1	0	0	1	90
0	0	1	0	1	1	0	1	0	91
0	0	1	0	1	1	0	1	1	92
0	0	1	0	1	1	1	0	0	93
0	0	1	0	1	1	1	0	1	94
0	0	1	0	1	1	1	1	0	95
0	0	1	0	1	1	1	1	1	96
0	0	1	1	0	0	0	0	0	97
0	0	1	1	0	0	0	0	1	98
0	0	1	1	0	0	0	1	0	99
0	0	1	1	0	0	0	1	1	100

256	128	64	32	16	8	4	2	1	Addr	256	128	64	32	16	8	4	2	1	Addr
0	0	1	1	0	0	1	0	0	101	0	1	0	1	0	0	0	0	0	161
0	0	1	1	0	0	1	0	1	102	0	1	0	1	0	0	0	0	1	162
0	0	1	1	0	0	1	1	0	103	0	1	0	1	0	0	0	1	0	163
0	0	1	1	0	0	1	1	1	104	0	1	0	1	0	0	0	1	1	164
0	0	1	1	0	1	0	0	0	105	0	1	0	1	0	0	1	0	0	165
0	0	1	1	0	1	0	0	1	106	0	1	0	1	0	0	1	0	1	166
0	0	1	1	0	1	0	1	0	107	0	1	0	1	0	0	1	1	0	167
0	0	1	1	0	1	0	1	1	108	0	1	0	1	0	0	1	1	1	168
0	0	1	1	0	1	1	0	0	109	0	1	0	1	0	1	0	0	0	169
0	0	1	1	0	1	1	0	1	110	0	1	0	1	0	1	0	0	1	170
0	0	1	1	0	1	1	1	0	111	0	1	0	1	0	1	0	1	0	171
0	0	1	1	0	1	1	1	1	112	0	1	0	1	0	1	0	1	1	172
0	0	1	1	1	0	0	0	0	113	0	1	0	1	0	1	1	0	0	173
0	0	1	1	1	0	0	0	1	114	0	1	0	1	0	1	1	0	1	174
0	0	1	1	1	0	0	1	0	115	0	1	0	1	0	1	1	1	0	175
0	0	1	1	1	0	0	1	1	116	0	1	0	1	0	1	1	1	1	176
0	0	1	1	1	0	1	0	0	117	0	1	0	1	1	0	0	0	0	177
0	0	1	1	1	0	1	0	1	118	0	1	0	1	1	0	0	0	1	178
0	0	1	1	1	0	1	1	0	119	0	1	0	1	1	0	0	1	0	179
0	0	1	1	1	0	1	1	1	120	0	1	0	1	1	0	0	1	1	180
0	0	1	1	1	1	0	0	0	121	0	1	0	1	1	0	1	0	0	181
0	0	1	1	1	1	0	0	1	122	0	1	0	1	1	0	1	0	1	182
0	0	1	1	1	1	0	1	0	123	0	1	0	1	1	0	1	1	0	183
0	0	1	1	1	1	0	1	1	124	0	1	0	1	1	0	1	1	1	184
0	0	1	1	1	1	1	0	0	125	0	1	0	1	1	1	0	0	0	185
0	0	1	1	1	1	1	0	1	126	0	1	0	1	1	1	0	0	1	186
0	0	1	1	1	1	1	1	0	127	0	1	0	1	1	1	0	1	0	187
0	0	1	1	1	1	1	1	1	128	0	1	0	1	1	1	0	1	1	188
0	1	0	0	0	0	0	0	0	129	0	1	0	1	1	1	1	0	0	189
0	1	0	0	0	0	0	0	1	130	0	1	0	1	1	1	1	0	1	190
0	1	0	0	0	0	0	1	0	131	0	1	0	1	1	1	1	1	0	191
0	1	0	0	0	0	0	1	1	132	0	1	0	1	1	1	1	1	1	192
0	1	0	0	0	0	1	0	0	133	0	1	1	0	0	0	0	0	0	193
0	1	0	0	0	0	1	0	1	134	0	1	1	0	0	0	0	0	1	194
0	1	0	0	0	0	1	1	0	135	0	1	1	0	0	0	0	1	0	195
0	1	0	0	0	0	1	1	1	136	0	1	1	0	0	0	0	1	1	196
0	1	0	0	0	1	0	0	0	137	0	1	1	0	0	0	1	0	0	197
0	1	0	0	0	1	0	0	1	138	0	1	1	0	0	0	1	0	1	198
0	1	0	0	0	1	0	1	0	139	0	1	1	0	0	0	1	1	0	199
0	1	0	0	0	1	0	1	1	140	0	1	1	0	0	0	1	1	1	200
0	1	0	0	0	1	1	0	0	141	0	1	1	0	0	1	0	0	0	201
0	1	0	0	0	1	1	0	1	142	0	1	1	0	0	1	0	0	1	202
0	1	0	0	0	1	1	1	0	143	0	1	1	0	0	1	0	1	0	203
0	1	0	0	0	1	1	1	1	144	0	1	1	0	0	1	0	1	1	204
0	1	0	0	1	0	0	0	0	145	0	1	1	0	0	1	1	0	0	205
0	1	0	0	1	0	0	0	1	146	0	1	1	0	0	1	1	0	1	206
0	1	0	0	1	0	0	1	0	147	0	1	1	0	0	1	1	1	0	207
0	1	0	0	1	0	0	1	1	148	0	1	1	0	0	1	1	1	1	208
0	1	0	0	1	0	1	0	0	149	0	1	1	0	1	0	0	0	0	209
0	1	0	0	1	0	1	0	1	150	0	1	1	0	1	0	0	0	1	210
0	1	0	0	1	0	1	1	0	151	0	1	1	0	1	0	0	1	0	211
0	1	0	0	1	0	1	1	1	152	0	1	1	0	1	0	0	1	1	212
0	1	0	0	1	1	0	0	0	153	0	1	1	0	1	0	1	0	0	213
0	1	0	0	1	1	0	0	1	154	0	1	1	0	1	0	1	0	1	214
0	1	0	0	1	1	0	1	0	155	0	1	1	0	1	0	1	1	0	215
0	1	0	0	1	1	0	1	1	156	0	1	1	0	1	0	1	1	1	216
0	1	0	0	1	1	1	0	0	157	0	1	1	0	1	1	0	0	0	217
0	1	0	0	1	1	1	0	1	158	0	1	1	0	1	1	0	0	1	218
0	1	0	0	1	1	1	1	0	159	0	1	1	0	1	1	0	1	0	219
0	1	0	0	1	1	1	1	1	160	0	1	1	0	1	1	0	1	1	220

256	128	64	32	16	8	4	2	1	Addr	256	128	64	32	16	8	4	2	1	Addr
0	1	1	0	1	1	1	0	0	221	1	0	0	0	1	1	0	0	0	281
0	1	1	0	1	1	1	0	1	222	1	0	0	0	1	1	0	0	1	282
0	1	1	0	1	1	1	1	0	223	1	0	0	0	1	1	0	1	0	283
0	1	1	0	1	1	1	1	1	224	1	0	0	0	1	1	0	1	1	284
0	1	1	1	0	0	0	0	0	225	1	0	0	0	1	1	1	0	0	285
0	1	1	1	0	0	0	0	1	226	1	0	0	0	1	1	1	0	1	286
0	1	1	1	0	0	0	1	0	227	1	0	0	0	1	1	1	1	0	287
0	1	1	1	0	0	0	1	1	228	1	0	0	0	1	1	1	1	1	288
0	1	1	1	0	0	1	0	0	229	1	0	0	1	0	0	0	0	0	289
0	1	1	1	0	0	1	0	1	230	1	0	0	1	0	0	0	0	1	290
0	1	1	1	0	0	1	1	0	231	1	0	0	1	0	0	0	1	0	291
0	1	1	1	0	0	1	1	1	232	1	0	0	1	0	0	0	1	1	292
0	1	1	1	0	1	0	0	0	233	1	0	0	1	0	0	1	0	0	293
0	1	1	1	0	1	0	0	1	234	1	0	0	1	0	0	1	0	1	294
0	1	1	1	0	1	0	1	0	235	1	0	0	1	0	0	1	1	0	295
0	1	1	1	0	1	0	1	1	236	1	0	0	1	0	0	1	1	1	296
0	1	1	1	0	1	1	0	0	237	1	0	0	1	0	1	0	0	0	297
0	1	1	1	0	1	1	0	1	238	1	0	0	1	0	1	0	0	1	298
0	1	1	1	0	1	1	1	0	239	1	0	0	1	0	1	0	1	0	299
0	1	1	1	0	1	1	1	1	240	1	0	0	1	0	1	0	1	1	300
0	1	1	1	1	0	0	0	0	241	1	0	0	1	0	1	1	0	0	301
0	1	1	1	1	0	0	0	1	242	1	0	0	1	0	1	1	0	1	302
0	1	1	1	1	0	0	1	0	243	1	0	0	1	0	1	1	1	0	303
0	1	1	1	1	0	0	1	1	244	1	0	0	1	0	1	1	1	1	304
0	1	1	1	1	0	1	0	0	245	1	0	0	1	1	0	0	0	0	305
0	1	1	1	1	0	1	0	1	246	1	0	0	1	1	0	0	0	1	306
0	1	1	1	1	0	1	1	0	247	1	0	0	1	1	0	0	1	0	307
0	1	1	1	1	0	1	1	1	248	1	0	0	1	1	0	0	1	1	308
0	1	1	1	1	1	0	0	0	249	1	0	0	1	1	0	1	0	0	309
0	1	1	1	1	1	0	0	1	250	1	0	0	1	1	0	1	0	1	310
0	1	1	1	1	1	0	1	0	251	1	0	0	1	1	0	1	1	0	311
0	1	1	1	1	1	0	1	1	252	1	0	0	1	1	0	1	1	1	312
0	1	1	1	1	1	1	0	0	253	1	0	0	1	1	1	0	0	0	313
0	1	1	1	1	1	1	0	1	254	1	0	0	1	1	1	0	0	1	314
0	1	1	1	1	1	1	1	0	255	1	0	0	1	1	1	0	1	0	315
0	1	1	1	1	1	1	1	1	256	1	0	0	1	1	1	0	1	1	316
1	0	0	0	0	0	0	0	0	257	1	0	0	1	1	1	1	0	0	317
1	0	0	0	0	0	0	0	1	258	1	0	0	1	1	1	1	0	1	318
1	0	0	0	0	0	0	1	0	259	1	0	0	1	1	1	1	1	0	319
1	0	0	0	0	0	0	1	1	260	1	0	0	1	1	1	1	1	1	320
1	0	0	0	0	0	1	0	0	261	1	0	1	0	0	0	0	0	0	321
1	0	0	0	0	0	1	0	1	262	1	0	1	0	0	0	0	0	1	322
1	0	0	0	0	0	1	1	0	263	1	0	1	0	0	0	0	1	0	323
1	0	0	0	0	0	1	1	1	264	1	0	1	0	0	0	0	1	1	324
1	0	0	0	0	1	0	0	0	265	1	0	1	0	0	0	1	0	0	325
1	0	0	0	0	1	0	0	1	266	1	0	1	0	0	0	1	0	1	326
1	0	0	0	0	1	0	1	0	267	1	0	1	0	0	0	1	1	0	327
1	0	0	0	0	1	0	1	1	268	1	0	1	0	0	0	1	1	1	328
1	0	0	0	0	1	1	0	0	269	1	0	1	0	0	1	0	0	0	329
1	0	0	0	0	1	1	0	1	270	1	0	1	0	0	1	0	0	1	330
1	0	0	0	0	1	1	1	0	271	1	0	1	0	0	1	0	1	0	331
1	0	0	0	0	1	1	1	1	272	1	0	1	0	0	1	0	1	1	332
1	0	0	0	1	0	0	0	0	273	1	0	1	0	0	1	1	0	0	333
1	0	0	0	1	0	0	0	1	274	1	0	1	0	0	1	1	0	1	334
1	0	0	0	1	0	0	1	0	275	1	0	1	0	0	1	1	1	0	335
1	0	0	0	1	0	0	1	1	276	1	0	1	0	0	1	1	1	1	336
1	0	0	0	1	0	1	0	0	277	1	0	1	0	1	0	0	0	0	337
1	0	0	0	1	0	1	0	1	278	1	0	1	0	1	0	0	0	1	338
1	0	0	0	1	0	1	1	0	279	1	0	1	0	1	0	0	1	0	339
1	0	0	0	1	0	1	1	1	280	1	0	1	0	1	0	0	1	1	340

256	128	64	32	16	8	4	2	1	Addr
1	0	1	0	1	0	1	0	0	341
1	0	1	0	1	0	1	0	1	342
1	0	1	0	1	0	1	1	0	343
1	0	1	0	1	0	1	1	1	344
1	0	1	0	1	1	0	0	0	345
1	0	1	0	1	1	0	0	1	346
1	0	1	0	1	1	0	1	0	347
1	0	1	0	1	1	0	1	1	348
1	0	1	0	1	1	1	0	0	349
1	0	1	0	1	1	1	0	1	350
1	0	1	0	1	1	1	1	0	351
1	0	1	0	1	1	1	1	1	352
1	0	1	1	0	0	0	0	0	353
1	0	1	1	0	0	0	0	1	354
1	0	1	1	0	0	0	1	0	355
1	0	1	1	0	0	0	1	1	356
1	0	1	1	0	0	1	0	0	357
1	0	1	1	0	0	1	0	1	358
1	0	1	1	0	0	1	1	0	359
1	0	1	1	0	0	1	1	1	360
1	0	1	1	0	1	0	0	0	361
1	0	1	1	0	1	0	0	1	362
1	0	1	1	0	1	0	1	0	363
1	0	1	1	0	1	0	1	1	364
1	0	1	1	0	1	1	0	0	365
1	0	1	1	0	1	1	0	1	366
1	0	1	1	0	1	1	1	0	367
1	0	1	1	0	1	1	1	1	368
1	0	1	1	1	0	0	0	0	369
1	0	1	1	1	0	0	0	1	370
1	0	1	1	1	0	0	1	0	371
1	0	1	1	1	0	0	1	1	372
1	0	1	1	1	0	1	0	0	373
1	0	1	1	1	0	1	0	1	374
1	0	1	1	1	0	1	1	0	375
1	0	1	1	1	0	1	1	1	376
1	0	1	1	1	1	0	0	0	377
1	0	1	1	1	1	0	0	1	378
1	0	1	1	1	1	0	1	0	379
1	0	1	1	1	1	0	1	1	380
1	0	1	1	1	1	1	0	0	381
1	0	1	1	1	1	1	0	1	382
1	0	1	1	1	1	1	1	0	383
1	0	1	1	1	1	1	1	1	384
1	1	0	0	0	0	0	0	0	385
1	1	0	0	0	0	0	0	1	386
1	1	0	0	0	0	0	1	0	387
1	1	0	0	0	0	0	1	1	388
1	1	0	0	0	0	1	0	0	389
1	1	0	0	0	0	1	0	1	390
1	1	0	0	0	0	1	1	0	391
1	1	0	0	0	0	1	1	1	392
1	1	0	0	0	1	0	0	0	393
1	1	0	0	0	1	0	0	1	394
1	1	0	0	0	1	0	1	0	395
1	1	0	0	0	1	0	1	1	396
1	1	0	0	0	1	1	0	0	397
1	1	0	0	0	1	1	0	1	398
1	1	0	0	0	1	1	1	0	399
1	1	0	0	0	1	1	1	1	400

256	128	64	32	16	8	4	2	1	Addr
1	1	0	0	1	0	0	0	0	401
1	1	0	0	1	0	0	0	1	402
1	1	0	0	1	0	0	1	0	403
1	1	0	0	1	0	0	1	1	404
1	1	0	0	1	0	1	0	0	405
1	1	0	0	1	0	1	0	1	406
1	1	0	0	1	0	1	1	0	407
1	1	0	0	1	0	1	1	1	408
1	1	0	0	1	1	0	0	0	409
1	1	0	0	1	1	0	0	1	410
1	1	0	0	1	1	0	1	0	411
1	1	0	0	1	1	0	1	1	412
1	1	0	0	1	1	1	0	0	413
1	1	0	0	1	1	1	0	1	414
1	1	0	0	1	1	1	1	0	415
1	1	0	0	1	1	1	1	1	416
1	1	0	1	0	0	0	0	0	417
1	1	0	1	0	0	0	0	1	418
1	1	0	1	0	0	0	1	0	419
1	1	0	1	0	0	0	1	1	420
1	1	0	1	0	0	1	0	0	421
1	1	0	1	0	0	1	0	1	422
1	1	0	1	0	0	1	1	0	423
1	1	0	1	0	0	1	1	1	424
1	1	0	1	0	1	0	0	0	425
1	1	0	1	0	1	0	0	1	426
1	1	0	1	0	1	0	1	0	427
1	1	0	1	0	1	0	1	1	428
1	1	0	1	0	1	1	0	0	429
1	1	0	1	0	1	1	0	1	430
1	1	0	1	0	1	1	1	0	431
1	1	0	1	0	1	1	1	1	432
1	1	0	1	1	0	0	0	0	433
1	1	0	1	1	0	0	0	1	434
1	1	0	1	1	0	0	1	0	435
1	1	0	1	1	0	0	1	1	436
1	1	0	1	1	0	1	0	0	437
1	1	0	1	1	0	1	0	1	438
1	1	0	1	1	0	1	1	0	439
1	1	0	1	1	0	1	1	1	440
1	1	0	1	1	1	0	0	0	441
1	1	0	1	1	1	0	0	1	442
1	1	0	1	1	1	0	1	0	443
1	1	0	1	1	1	0	1	1	444
1	1	0	1	1	1	1	0	0	445
1	1	0	1	1	1	1	0	1	446
1	1	0	1	1	1	1	1	0	447
1	1	0	1	1	1	1	1	1	448
1	1	1	0	0	0	0	0	0	449
1	1	1	0	0	0	0	0	1	450
1	1	1	0	0	0	0	1	0	451
1	1	1	0	0	0	0	1	1	452
1	1	1	0	0	0	1	0	0	453
1	1	1	0	0	0	1	0	1	454
1	1	1	0	0	0	1	1	0	455
1	1	1	0	0	0	1	1	1	456
1	1	1	0	0	1	0	0	0	457
1	1	1	0	0	1	0	0	1	458
1	1	1	0	0	1	0	1	0	459
1	1	1	0	0	1	0	1	1	460

256	128	64	32	16	8	4	2	1	Addr
1	1	1	0	0	1	1	0	0	461
1	1	1	0	0	1	1	0	1	462
1	1	1	0	0	1	1	1	0	463
1	1	1	0	0	1	1	1	1	464
1	1	1	0	1	0	0	0	0	465
1	1	1	0	1	0	0	0	1	466
1	1	1	0	1	0	0	1	0	467
1	1	1	0	1	0	0	1	1	468
1	1	1	0	1	0	1	0	0	469
1	1	1	0	1	0	1	0	1	470
1	1	1	0	1	0	1	1	0	471
1	1	1	0	1	0	1	1	1	472
1	1	1	0	1	1	0	0	0	473
1	1	1	0	1	1	0	0	1	474
1	1	1	0	1	1	0	1	0	475
1	1	1	0	1	1	0	1	1	476
1	1	1	0	1	1	1	0	0	477
1	1	1	0	1	1	1	0	1	478
1	1	1	0	1	1	1	1	0	479
1	1	1	0	1	1	1	1	1	480
1	1	1	1	0	0	0	0	0	481
1	1	1	1	0	0	0	0	1	482
1	1	1	1	0	0	0	1	0	483
1	1	1	1	0	0	0	1	1	484
1	1	1	1	0	0	1	0	0	485
1	1	1	1	0	0	1	0	1	486

256	128	64	32	16	8	4	2	1	Addr
1	1	1	1	0	0	1	1	0	487
1	1	1	1	0	0	1	1	1	488
1	1	1	1	0	1	0	0	0	489
1	1	1	1	0	1	0	0	1	490
1	1	1	1	0	1	0	1	0	491
1	1	1	1	0	1	0	1	1	492
1	1	1	1	0	1	1	0	0	493
1	1	1	1	0	1	1	0	1	494
1	1	1	1	0	1	1	1	0	495
1	1	1	1	0	1	1	1	1	496
1	1	1	1	1	0	0	0	0	497
1	1	1	1	1	0	0	0	1	498
1	1	1	1	1	0	0	1	0	499
1	1	1	1	1	0	0	1	1	500
1	1	1	1	1	0	1	0	0	501
1	1	1	1	1	0	1	0	1	502
1	1	1	1	1	0	1	1	0	503
1	1	1	1	1	0	1	1	1	504
1	1	1	1	1	1	0	0	0	505
1	1	1	1	1	1	0	0	1	506
1	1	1	1	1	1	0	1	0	507
1	1	1	1	1	1	0	1	1	508
1	1	1	1	1	1	1	0	0	509
1	1	1	1	1	1	1	0	1	510
1	1	1	1	1	1	1	1	0	511
1	1	1	1	1	1	1	1	1	512

DMX512 'universe' address offsets:

When a system comprises more than 512 receiving device channels, additional DMX512 lines are employed. Thus, a console with 1024 output channels will be fitted with two DMX512 output ports, one with 1536 output channels will be fitted with three DMX512 output ports, and so on.

Each of these 512 channel ports are also known as 'DMX universes'. In most cases however, receivers have only one input port, with addressing selectable in the range 1-512. In order to set a device to respond to, say, console output channel 1200 it is necessary to connect to console port 3 and set the address to 1200-512-512 = 176, universe 3.

The following table lists the relation between sequentially numbered DMX512 channels, as they would appear on the console, and universe numbered channels in blocks of 512, as they would appear on a receiving device.

Device address	Port 1	Port 2	Port 3	Port 4	Port 5	Port 6
1	1	513	1025	1537	2049	2561
2	2	514	1026	1538	2050	2562
3	3	515	1027	1539	2051	2563
4	4	516	1028	1540	2052	2564
5	5	517	1029	1541	2053	2565
6	6	518	1030	1542	2054	2566
7	7	519	1031	1543	2055	2567
8	8	520	1032	1544	2056	2568
9	9	521	1033	1545	2057	2569
10	10	522	1034	1546	2058	2570
11	11	523	1035	1547	2059	2571
12	12	524	1036	1548	2060	2572
13	13	525	1037	1549	2061	2573
14	14	526	1038	1550	2062	2574
15	15	527	1039	1551	2063	2575
16	16	528	1040	1552	2064	2576
17	17	529	1041	1553	2065	2577
18	18	530	1042	1554	2066	2578
19	19	531	1043	1555	2067	2579
20	20	532	1044	1556	2068	2580
21	21	533	1045	1557	2069	2581
22	22	534	1046	1558	2070	2582
23	23	535	1047	1559	2071	2583
24	24	536	1048	1560	2072	2584
25	25	537	1049	1561	2073	2585
26	26	538	1050	1562	2074	2586
27	27	539	1051	1563	2075	2587
28	28	540	1052	1564	2076	2588
29	29	541	1053	1565	2077	2589
30	30	542	1054	1566	2078	2590
31	31	543	1055	1567	2079	2591
32	32	544	1056	1568	2080	2592
33	33	545	1057	1569	2081	2593
34	34	546	1058	1570	2082	2594
35	35	547	1059	1571	2083	2595
36	36	548	1060	1572	2084	2596
37	37	549	1061	1573	2085	2597
38	38	550	1062	1574	2086	2598
39	39	551	1063	1575	2087	2599
40	40	552	1064	1576	2088	2600
41	41	553	1065	1577	2089	2601
42	42	554	1066	1578	2090	2602
43	43	555	1067	1579	2091	2603
44	44	556	1068	1580	2092	2604
45	45	557	1069	1581	2093	2605
46	46	558	1070	1582	2094	2606
47	47	559	1071	1583	2095	2607
48	48	560	1072	1584	2096	2608
49	49	561	1073	1585	2097	2609
50	50	562	1074	1586	2098	2610
51	51	563	1075	1587	2099	2611
52	52	564	1076	1588	2100	2612
53	53	565	1077	1589	2101	2613
54	54	566	1078	1590	2102	2614
55	55	567	1079	1591	2103	2615
56	56	568	1080	1592	2104	2616

Device address	Port 1	Port 2	Port 3	Port 4	Port 5	Port 6
57	57	569	1081	1593	2105	2617
58	58	570	1082	1594	2106	2618
59	59	571	1083	1595	2107	2619
60	60	572	1084	1596	2108	2620
61	61	573	1085	1597	2109	2621
62	62	574	1086	1598	2110	2622
63	63	575	1087	1599	2111	2623
64	64	576	1088	1600	2112	2624
65	65	577	1089	1601	2113	2625
66	66	578	1090	1602	2114	2626
67	67	579	1091	1603	2115	2627
68	68	580	1092	1604	2116	2628
69	69	581	1093	1605	2117	2629
70	70	582	1094	1606	2118	2630
71	71	583	1095	1607	2119	2631
72	72	584	1096	1608	2120	2632
73	73	585	1097	1609	2121	2633
74	74	586	1098	1610	2122	2634
75	75	587	1099	1611	2123	2635
76	76	588	1100	1612	2124	2636
77	77	589	1101	1613	2125	2637
78	78	590	1102	1614	2126	2638
79	79	591	1103	1615	2127	2639
80	80	592	1104	1616	2128	2640
81	81	593	1105	1617	2129	2641
82	82	594	1106	1618	2130	2642
83	83	595	1107	1619	2131	2643
84	84	596	1108	1620	2132	2644
85	85	597	1109	1621	2133	2645
86	86	598	1110	1622	2134	2646
87	87	599	1111	1623	2135	2647
88	88	600	1112	1624	2136	2648
89	89	601	1113	1625	2137	2649
90	90	602	1114	1626	2138	2650
91	91	603	1115	1627	2139	2651
92	92	604	1116	1628	2140	2652
93	93	605	1117	1629	2141	2653
94	94	606	1118	1630	2142	2654
95	95	607	1119	1631	2143	2655
96	96	608	1120	1632	2144	2656
97	97	609	1121	1633	2145	2657
98	98	610	1122	1634	2146	2658
99	99	611	1123	1635	2147	2659
100	100	612	1124	1636	2148	2660
101	101	613	1125	1637	2149	2661
102	102	614	1126	1638	2150	2662
103	103	615	1127	1639	2151	2663
104	104	616	1128	1640	2152	2664
105	105	617	1129	1641	2153	2665
106	106	618	1130	1642	2154	2666
107	107	619	1131	1643	2155	2667
108	108	620	1132	1644	2156	2668
109	109	621	1133	1645	2157	2669
110	110	622	1134	1646	2158	2670
111	111	623	1135	1647	2159	2671
112	112	624	1136	1648	2160	2672
113	113	625	1137	1649	2161	2673
114	114	626	1138	1650	2162	2674
115	115	627	1139	1651	2163	2675

Device address	Port 1	Port 2	Port 3	Port 4	Port 5	Port 6
116	116	628	1140	1652	2164	2676
117	117	629	1141	1653	2165	2677
118	118	630	1142	1654	2166	2678
119	119	631	1143	1655	2167	2679
120	120	632	1144	1656	2168	2680
121	121	633	1145	1657	2169	2681
122	122	634	1146	1658	2170	2682
123	123	635	1147	1659	2171	2683
124	124	636	1148	1660	2172	2684
125	125	637	1149	1661	2173	2685
126	126	638	1150	1662	2174	2686
127	127	639	1151	1663	2175	2687
128	128	640	1152	1664	2176	2688
129	129	641	1153	1665	2177	2689
130	130	642	1154	1666	2178	2690
131	131	643	1155	1667	2179	2691
132	132	644	1156	1668	2180	2692
133	133	645	1157	1669	2181	2693
134	134	646	1158	1670	2182	2694
135	135	647	1159	1671	2183	2695
136	136	648	1160	1672	2184	2696
137	137	649	1161	1673	2185	2697
138	138	650	1162	1674	2186	2698
139	139	651	1163	1675	2187	2699
140	140	652	1164	1676	2188	2700
141	141	653	1165	1677	2189	2701
142	142	654	1166	1678	2190	2702
143	143	655	1167	1679	2191	2703
144	144	656	1168	1680	2192	2704
145	145	657	1169	1681	2193	2705
146	146	658	1170	1682	2194	2706
147	147	659	1171	1683	2195	2707
148	148	660	1172	1684	2196	2708
149	149	661	1173	1685	2197	2709
150	150	662	1174	1686	2198	2710
151	151	663	1175	1687	2199	2711
152	152	664	1176	1688	2200	2712
153	153	665	1177	1689	2201	2713
154	154	666	1178	1690	2202	2714
155	155	667	1179	1691	2203	2715
156	156	668	1180	1692	2204	2716
157	157	669	1181	1693	2205	2717
158	158	670	1182	1694	2206	2718
159	159	671	1183	1695	2207	2719
160	160	672	1184	1696	2208	2720
161	161	673	1185	1697	2209	2721
162	162	674	1186	1698	2210	2722
163	163	675	1187	1699	2211	2723
164	164	676	1188	1700	2212	2724
165	165	677	1189	1701	2213	2725
166	166	678	1190	1702	2214	2726
167	167	679	1191	1703	2215	2727
168	168	680	1192	1704	2216	2728
169	169	681	1193	1705	2217	2729
170	170	682	1194	1706	2218	2730
171	171	683	1195	1707	2219	2731
172	172	684	1196	1708	2220	2732
173	173	685	1197	1709	2221	2733
174	174	686	1198	1710	2222	2734

Device address	Port 1	Port 2	Port 3	Port 4	Port 5	Port 6
175	175	687	1199	1711	2223	2735
176	176	688	1200	1712	2224	2736
177	177	689	1201	1713	2225	2737
178	178	690	1202	1714	2226	2738
179	179	691	1203	1715	2227	2739
180	180	692	1204	1716	2228	2740
181	181	693	1205	1717	2229	2741
182	182	694	1206	1718	2230	2742
183	183	695	1207	1719	2231	2743
184	184	696	1208	1720	2232	2744
185	185	697	1209	1721	2233	2745
186	186	698	1210	1722	2234	2746
187	187	699	1211	1723	2235	2747
188	188	700	1212	1724	2236	2748
189	189	701	1213	1725	2237	2749
190	190	702	1214	1726	2238	2750
191	191	703	1215	1727	2239	2751
192	192	704	1216	1728	2240	2752
193	193	705	1217	1729	2241	2753
194	194	706	1218	1730	2242	2754
195	195	707	1219	1731	2243	2755
196	196	708	1220	1732	2244	2756
197	197	709	1221	1733	2245	2757
198	198	710	1222	1734	2246	2758
199	199	711	1223	1735	2247	2759
200	200	712	1224	1736	2248	2760
201	201	713	1225	1737	2249	2761
202	202	714	1226	1738	2250	2762
203	203	715	1227	1739	2251	2763
204	204	716	1228	1740	2252	2764
205	205	717	1229	1741	2253	2765
206	206	718	1230	1742	2254	2766
207	207	719	1231	1743	2255	2767
208	208	720	1232	1744	2256	2768
209	209	721	1233	1745	2257	2769
210	210	722	1234	1746	2258	2770
211	211	723	1235	1747	2259	2771
212	212	724	1236	1748	2260	2772
213	213	725	1237	1749	2261	2773
214	214	726	1238	1750	2262	2774
215	215	727	1239	1751	2263	2775
216	216	728	1240	1752	2264	2776
217	217	729	1241	1753	2265	2777
218	218	730	1242	1754	2266	2778
219	219	731	1243	1755	2267	2779
220	220	732	1244	1756	2268	2780
221	221	733	1245	1757	2269	2781
222	222	734	1246	1758	2270	2782
223	223	735	1247	1759	2271	2783
224	224	736	1248	1760	2272	2784
225	225	737	1249	1761	2273	2785
226	226	738	1250	1762	2274	2786
227	227	739	1251	1763	2275	2787
228	228	740	1252	1764	2276	2788
229	229	741	1253	1765	2277	2789
230	230	742	1254	1766	2278	2790
231	231	743	1255	1767	2279	2791
232	232	744	1256	1768	2280	2792
233	233	745	1257	1769	2281	2793
234	234	746	1258	1770	2282	2794
235	235	747	1259	1771	2283	2795
236	236	748	1260	1772	2284	2796
237	237	749	1261	1773	2285	2797
238	238	750	1262	1774	2286	2798
239	239	751	1263	1775	2287	2799
240	240	752	1264	1776	2288	2800
241	241	753	1265	1777	2289	2801
242	242	754	1266	1778	2290	2802
243	243	755	1267	1779	2291	2803
244	244	756	1268	1780	2292	2804
245	245	757	1269	1781	2293	2805
246	246	758	1270	1782	2294	2806
247	247	759	1271	1783	2295	2807
248	248	760	1272	1784	2296	2808
249	249	761	1273	1785	2297	2809
250	250	762	1274	1786	2298	2810
251	251	763	1275	1787	2299	2811
252	252	764	1276	1788	2300	2812
253	253	765	1277	1789	2301	2813
254	254	766	1278	1790	2302	2814
255	255	767	1279	1791	2303	2815
256	256	768	1280	1792	2304	2816
257	257	769	1281	1793	2305	2817
258	258	770	1282	1794	2306	2818
259	259	771	1283	1795	2307	2819
260	260	772	1284	1796	2308	2820
261	261	773	1285	1797	2309	2821
262	262	774	1286	1798	2310	2822
263	263	775	1287	1799	2311	2823
264	264	776	1288	1800	2312	2824
265	265	777	1289	1801	2313	2825
266	266	778	1290	1802	2314	2826
267	267	779	1291	1803	2315	2827
268	268	780	1292	1804	2316	2828
269	269	781	1293	1805	2317	2829
270	270	782	1294	1806	2318	2830
271	271	783	1295	1807	2319	2831
272	272	784	1296	1808	2320	2832
273	273	785	1297	1809	2321	2833
274	274	786	1298	1810	2322	2834
275	275	787	1299	1811	2323	2835
276	276	788	1300	1812	2324	2836
277	277	789	1301	1813	2325	2837
278	278	790	1302	1814	2326	2838
279	279	791	1303	1815	2327	2839
280	280	792	1304	1816	2328	2840
281	281	793	1305	1817	2329	2841
282	282	794	1306	1818	2330	2842
283	283	795	1307	1819	2331	2843
284	284	796	1308	1820	2332	2844
285	285	797	1309	1821	2333	2845
286	286	798	1310	1822	2334	2846
287	287	799	1311	1823	2335	2847
288	288	800	1312	1824	2336	2848
289	289	801	1313	1825	2337	2849
290	290	802	1314	1826	2338	2850
291	291	803	1315	1827	2339	2851
292	292	804	1316	1828	2340	2852

Device address	Port 1	Port 2	Port 3	Port 4	Port 5	Port 6
293	293	805	1317	1829	2341	2853
294	294	806	1318	1830	2342	2854
295	295	807	1319	1831	2343	2855
296	296	808	1320	1832	2344	2856
297	297	809	1321	1833	2345	2857
298	298	810	1322	1834	2346	2858
299	299	811	1323	1835	2347	2859
300	300	812	1324	1836	2348	2860
301	301	813	1325	1837	2349	2861
302	302	814	1326	1838	2350	2862
303	303	815	1327	1839	2351	2863
304	304	816	1328	1840	2352	2864
305	305	817	1329	1841	2353	2865
306	306	818	1330	1842	2354	2866
307	307	819	1331	1843	2355	2867
308	308	820	1332	1844	2356	2868
309	309	821	1333	1845	2357	2869
310	310	822	1334	1846	2358	2870
311	311	823	1335	1847	2359	2871
312	312	824	1336	1848	2360	2872
313	313	825	1337	1849	2361	2873
314	314	826	1338	1850	2362	2874
315	315	827	1339	1851	2363	2875
316	316	828	1340	1852	2364	2876
317	317	829	1341	1853	2365	2877
318	318	830	1342	1854	2366	2878
319	319	831	1343	1855	2367	2879
320	320	832	1344	1856	2368	2880
321	321	833	1345	1857	2369	2881
322	322	834	1346	1858	2370	2882
323	323	835	1347	1859	2371	2883
324	324	836	1348	1860	2372	2884
325	325	837	1349	1861	2373	2885
326	326	838	1350	1862	2374	2886
327	327	839	1351	1863	2375	2887
328	328	840	1352	1864	2376	2888
329	329	841	1353	1865	2377	2889
330	330	842	1354	1866	2378	2890
331	331	843	1355	1867	2379	2891
332	332	844	1356	1868	2380	2892
333	333	845	1357	1869	2381	2893
334	334	846	1358	1870	2382	2894
335	335	847	1359	1871	2383	2895
336	336	848	1360	1872	2384	2896
337	337	849	1361	1873	2385	2897
338	338	850	1362	1874	2386	2898
339	339	851	1363	1875	2387	2899
340	340	852	1364	1876	2388	2900
341	341	853	1365	1877	2389	2901
342	342	854	1366	1878	2390	2902
343	343	855	1367	1879	2391	2903
344	344	856	1368	1880	2392	2904
345	345	857	1369	1881	2393	2905
346	346	858	1370	1882	2394	2906
347	347	859	1371	1883	2395	2907
348	348	860	1372	1884	2396	2908
349	349	861	1373	1885	2397	2909
350	350	862	1374	1886	2398	2910
351	351	863	1375	1887	2399	2911

Device address	Port 1	Port 2	Port 3	Port 4	Port 5	Port 6
352	352	864	1376	1888	2400	2912
353	353	865	1377	1889	2401	2913
354	354	866	1378	1890	2402	2914
355	355	867	1379	1891	2403	2915
356	356	868	1380	1892	2404	2916
357	357	869	1381	1893	2405	2917
358	358	870	1382	1894	2406	2918
359	359	871	1383	1895	2407	2919
360	360	872	1384	1896	2408	2920
361	361	873	1385	1897	2409	2921
362	362	874	1386	1898	2410	2922
363	363	875	1387	1899	2411	2923
364	364	876	1388	1900	2412	2924
365	365	877	1389	1901	2413	2925
366	366	878	1390	1902	2414	2926
367	367	879	1391	1903	2415	2927
368	368	880	1392	1904	2416	2928
369	369	881	1393	1905	2417	2929
370	370	882	1394	1906	2418	2930
371	371	883	1395	1907	2419	2931
372	372	884	1396	1908	2420	2932
373	373	885	1397	1909	2421	2933
374	374	886	1398	1910	2422	2934
375	375	887	1399	1911	2423	2935
376	376	888	1400	1912	2424	2936
377	377	889	1401	1913	2425	2937
378	378	890	1402	1914	2426	2938
379	379	891	1403	1915	2427	2939
380	380	892	1404	1916	2428	2940
381	381	893	1405	1917	2429	2941
382	382	894	1406	1918	2430	2942
383	383	895	1407	1919	2431	2943
384	384	896	1408	1920	2432	2944
385	385	897	1409	1921	2433	2945
386	386	898	1410	1922	2434	2946
387	387	899	1411	1923	2435	2947
388	388	900	1412	1924	2436	2948
389	389	901	1413	1925	2437	2949
390	390	902	1414	1926	2438	2950
391	391	903	1415	1927	2439	2951
392	392	904	1416	1928	2440	2952
393	393	905	1417	1929	2441	2953
394	394	906	1418	1930	2442	2954
395	395	907	1419	1931	2443	2955
396	396	908	1420	1932	2444	2956
397	397	909	1421	1933	2445	2957
398	398	910	1422	1934	2446	2958
399	399	911	1423	1935	2447	2959
400	400	912	1424	1936	2448	2960
401	401	913	1425	1937	2449	2961
402	402	914	1426	1938	2450	2962
403	403	915	1427	1939	2451	2963
404	404	916	1428	1940	2452	2964
405	405	917	1429	1941	2453	2965
406	406	918	1430	1942	2454	2966
407	407	919	1431	1943	2455	2967
408	408	920	1432	1944	2456	2968
409	409	921	1433	1945	2457	2969
410	410	922	1434	1946	2458	2970

Device address	Port 1	Port 2	Port 3	Port 4	Port 5	Port 6
411	411	923	1435	1947	2459	2971
412	412	924	1436	1948	2460	2972
413	413	925	1437	1949	2461	2973
414	414	926	1438	1950	2462	2974
415	415	927	1439	1951	2463	2975
416	416	928	1440	1952	2464	2976
417	417	929	1441	1953	2465	2977
418	418	930	1442	1954	2466	2978
419	419	931	1443	1955	2467	2979
420	420	932	1444	1956	2468	2980
421	421	933	1445	1957	2469	2981
422	422	934	1446	1958	2470	2982
423	423	935	1447	1959	2471	2983
424	424	936	1448	1960	2472	2984
425	425	937	1449	1961	2473	2985
426	426	938	1450	1962	2474	2986
427	427	939	1451	1963	2475	2987
428	428	940	1452	1964	2476	2988
429	429	941	1453	1965	2477	2989
430	430	942	1454	1966	2478	2990
431	431	943	1455	1967	2479	2991
432	432	944	1456	1968	2480	2992
433	433	945	1457	1969	2481	2993
434	434	946	1458	1970	2482	2994
435	435	947	1459	1971	2483	2995
436	436	948	1460	1972	2484	2996
437	437	949	1461	1973	2485	2997
438	438	950	1462	1974	2486	2998
439	439	951	1463	1975	2487	2999
440	440	952	1464	1976	2488	3000
441	441	953	1465	1977	2489	3001
442	442	954	1466	1978	2490	3002
443	443	955	1467	1979	2491	3003
444	444	956	1468	1980	2492	3004
445	445	957	1469	1981	2493	3005
446	446	958	1470	1982	2494	3006
447	447	959	1471	1983	2495	3007
448	448	960	1472	1984	2496	3008
449	449	961	1473	1985	2497	3009
450	450	962	1474	1986	2498	3010
451	451	963	1475	1987	2499	3011
452	452	964	1476	1988	2500	3012
453	453	965	1477	1989	2501	3013
454	454	966	1478	1990	2502	3014
455	455	967	1479	1991	2503	3015
456	456	968	1480	1992	2504	3016
457	457	969	1481	1993	2505	3017
458	458	970	1482	1994	2506	3018
459	459	971	1483	1995	2507	3019
460	460	972	1484	1996	2508	3020
461	461	973	1485	1997	2509	3021
462	462	974	1486	1998	2510	3022
463	463	975	1487	1999	2511	3023
464	464	976	1488	2000	2512	3024
465	465	977	1489	2001	2513	3025
466	466	978	1490	2002	2514	3026
467	467	979	1491	2003	2515	3027
468	468	980	1492	2004	2516	3028
469	469	981	1493	2005	2517	3029
470	470	982	1494	2006	2518	3030
471	471	983	1495	2007	2519	3031
472	472	984	1496	2008	2520	3032
473	473	985	1497	2009	2521	3033
474	474	986	1498	2010	2522	3034
475	475	987	1499	2011	2523	3035
476	476	988	1500	2012	2524	3036
477	477	989	1501	2013	2525	3037
478	478	990	1502	2014	2526	3038
479	479	991	1503	2015	2527	3039
480	480	992	1504	2016	2528	3040
481	481	993	1505	2017	2529	3041
482	482	994	1506	2018	2530	3042
483	483	995	1507	2019	2531	3043
484	484	996	1508	2020	2532	3044
485	485	997	1509	2021	2533	3045
486	486	998	1510	2022	2534	3046
487	487	999	1511	2023	2535	3047
488	488	1000	1512	2024	2536	3048
489	489	1001	1513	2025	2537	3049
490	490	1002	1514	2026	2538	3050
491	491	1003	1515	2027	2539	3051
492	492	1004	1516	2028	2540	3052
493	493	1005	1517	2029	2541	3053
494	494	1006	1518	2030	2542	3054
495	495	1007	1519	2031	2543	3055
496	496	1008	1520	2032	2544	3056
497	497	1009	1521	2033	2545	3057
498	498	1010	1522	2034	2546	3058
499	499	1011	1523	2035	2547	3059
500	500	1012	1524	2036	2548	3060
501	501	1013	1525	2037	2549	3061
502	502	1014	1526	2038	2550	3062
503	503	1015	1527	2039	2551	3063
504	504	1016	1528	2040	2552	3064
505	505	1017	1529	2041	2553	3065
506	506	1018	1530	2042	2554	3066
507	507	1019	1531	2043	2555	3067
508	508	1020	1532	2044	2556	3068
509	509	1021	1533	2045	2557	3069
510	510	1022	1534	2046	2558	3070
511	511	1023	1535	2047	2559	3071
512	512	1024	1536	2048	2560	3072

Binary/Hexadecimal/Decimal conversions:

key:

128 - 1 Binary number, m.s.b. to left

$ Hexadecimal number, base 16, $00 - $FF

Decimal number, 0 - 255

% Approximate percentage of full scale (depends on console design)

128	64	32	16	8	4	2	1	$	#	%
0	0	0	0	0	0	0	0	00	0	0
0	0	0	0	0	0	0	1	01	1	
0	0	0	0	0	0	1	0	02	2	
0	0	0	0	0	0	1	1	03	3	
0	0	0	0	0	1	0	0	04	4	
0	0	0	0	0	1	0	1	05	5	
0	0	0	0	0	1	1	0	06	6	
0	0	0	0	0	1	1	1	07	7	
0	0	0	0	1	0	0	0	08	8	
0	0	0	0	1	0	0	1	09	9	
0	0	0	0	1	0	1	0	0A	10	
0	0	0	0	1	0	1	1	0B	11	
0	0	0	0	1	1	0	0	0C	12	5
0	0	0	0	1	1	0	1	0D	13	
0	0	0	0	1	1	1	0	0E	14	
0	0	0	0	1	1	1	1	0F	15	
0	0	0	1	0	0	0	0	10	16	
0	0	0	1	0	0	0	1	11	17	
0	0	0	1	0	0	1	0	12	18	
0	0	0	1	0	0	1	1	13	19	
0	0	0	1	0	1	0	0	14	20	
0	0	0	1	0	1	0	1	15	21	
0	0	0	1	0	1	1	0	16	22	
0	0	0	1	0	1	1	1	17	23	
0	0	0	1	1	0	0	0	18	24	
0	0	0	1	1	0	0	1	19	25	10
0	0	0	1	1	0	1	0	1A	26	
0	0	0	1	1	0	1	1	1B	27	
0	0	0	1	1	1	0	0	1C	28	
0	0	0	1	1	1	0	1	1D	29	
0	0	0	1	1	1	1	0	1E	30	
0	0	0	1	1	1	1	1	1F	31	
0	0	1	0	0	0	0	0	20	32	
0	0	1	0	0	0	0	1	21	33	
0	0	1	0	0	0	1	0	22	34	
0	0	1	0	0	0	1	1	23	35	
0	0	1	0	0	1	0	0	24	36	
0	0	1	0	0	1	0	1	25	37	15
0	0	1	0	0	1	1	0	26	38	
0	0	1	0	0	1	1	1	27	39	
0	0	1	0	1	0	0	0	28	40	

128	64	32	16	8	4	2	1	$	#	%
0	0	1	0	1	0	0	1	29	41	
0	0	1	0	1	0	1	0	2A	42	
0	0	1	0	1	0	1	1	2B	43	
0	0	1	0	1	1	0	0	2C	44	
0	0	1	0	1	1	0	1	2D	45	
0	0	1	0	1	1	1	0	2E	46	
0	0	1	0	1	1	1	1	2F	47	
0	0	1	1	0	0	0	0	30	48	
0	0	1	1	0	0	0	1	31	49	
0	0	1	1	0	0	1	0	32	50	
0	0	1	1	0	0	1	1	33	51	20
0	0	1	1	0	1	0	0	34	52	
0	0	1	1	0	1	0	1	35	53	
0	0	1	1	0	1	1	0	36	54	
0	0	1	1	0	1	1	1	37	55	
0	0	1	1	1	0	0	0	38	56	
0	0	1	1	1	0	0	1	39	57	
0	0	1	1	1	0	1	0	3A	58	
0	0	1	1	1	0	1	1	3B	59	
0	0	1	1	1	1	0	0	3C	60	
0	0	1	1	1	1	0	1	3D	61	
0	0	1	1	1	1	1	0	3E	62	
0	0	1	1	1	1	1	1	3F	63	25
0	1	0	0	0	0	0	0	40	64	
0	1	0	0	0	0	0	1	41	65	
0	1	0	0	0	0	1	0	42	66	
0	1	0	0	0	0	1	1	43	67	
0	1	0	0	0	1	0	0	44	68	
0	1	0	0	0	1	0	1	45	69	
0	1	0	0	0	1	1	0	46	70	
0	1	0	0	0	1	1	1	47	71	
0	1	0	0	1	0	0	0	48	72	
0	1	0	0	1	0	0	1	49	73	
0	1	0	0	1	0	1	0	4A	74	
0	1	0	0	1	0	1	1	4B	75	
0	1	0	0	1	1	0	0	4C	76	30
0	1	0	0	1	1	0	1	4D	77	
0	1	0	0	1	1	1	0	4E	78	
0	1	0	0	1	1	1	1	4F	79	
0	1	0	1	0	0	0	0	50	80	
0	1	0	1	0	0	0	1	51	81	

128	64	32	16	8	4	2	1	$	#	%
0	1	0	1	0	0	1	0	52	82	
0	1	0	1	0	0	1	1	53	83	
0	1	0	1	0	1	0	0	54	84	
0	1	0	1	0	1	0	1	55	85	
0	1	0	1	0	1	1	0	56	86	
0	1	0	1	0	1	1	1	57	87	35
0	1	0	1	1	0	0	0	58	88	
0	1	0	1	1	0	0	1	59	89	
0	1	0	1	1	0	1	0	5A	90	
0	1	0	1	1	0	1	1	5B	91	
0	1	0	1	1	1	0	0	5C	92	
0	1	0	1	1	1	0	1	5D	93	
0	1	0	1	1	1	1	0	5E	94	
0	1	0	1	1	1	1	1	5F	95	
0	1	1	0	0	0	0	0	60	96	
0	1	1	0	0	0	0	1	61	97	
0	1	1	0	0	0	1	0	62	98	
0	1	1	0	0	0	1	1	63	99	
0	1	1	0	0	1	0	0	64	100	
0	1	1	0	0	1	0	1	65	101	40
0	1	1	0	0	1	1	0	66	102	
0	1	1	0	0	1	1	1	67	103	
0	1	1	0	1	0	0	0	68	104	
0	1	1	0	1	0	0	1	69	105	
0	1	1	0	1	0	1	0	6A	106	
0	1	1	0	1	0	1	1	6B	107	
0	1	1	0	1	1	0	0	6C	108	
0	1	1	0	1	1	0	1	6D	109	
0	1	1	0	1	1	1	0	6E	110	
0	1	1	0	1	1	1	1	6F	111	
0	1	1	1	0	0	0	0	70	112	
0	1	1	1	0	0	0	1	71	113	
0	1	1	1	0	0	1	0	72	114	45
0	1	1	1	0	0	1	1	73	115	
0	1	1	1	0	1	0	0	74	116	
0	1	1	1	0	1	0	1	75	117	
0	1	1	1	0	1	1	0	76	118	
0	1	1	1	0	1	1	1	77	119	
0	1	1	1	1	0	0	0	78	120	
0	1	1	1	1	0	0	1	79	121	
0	1	1	1	1	0	1	0	7A	122	
0	1	1	1	1	0	1	1	7B	123	
0	1	1	1	1	1	0	0	7C	124	
0	1	1	1	1	1	0	1	7D	125	
0	1	1	1	1	1	1	0	7E	126	
0	1	1	1	1	1	1	1	7F	127	50
1	0	0	0	0	0	0	0	80	128	
1	0	0	0	0	0	0	1	81	129	
1	0	0	0	0	0	1	0	82	130	
1	0	0	0	0	0	1	1	83	131	
1	0	0	0	0	1	0	0	84	132	
1	0	0	0	0	1	0	1	85	133	
1	0	0	0	0	1	1	0	86	134	
1	0	0	0	0	1	1	1	87	135	
1	0	0	0	1	0	0	0	88	136	
1	0	0	0	1	0	0	1	89	137	
1	0	0	0	1	0	1	0	8A	138	
1	0	0	0	1	0	1	1	8B	139	
1	0	0	0	1	1	0	0	8C	140	55
1	0	0	0	1	1	0	1	8D	141	
1	0	0	0	1	1	1	0	8E	142	
1	0	0	0	1	1	1	1	8F	143	
1	0	0	1	0	0	0	0	90	144	
1	0	0	1	0	0	0	1	91	145	
1	0	0	1	0	0	1	0	92	146	
1	0	0	1	0	0	1	1	93	147	
1	0	0	1	0	1	0	0	94	148	
1	0	0	1	0	1	0	1	95	149	
1	0	0	1	0	1	1	0	96	150	
1	0	0	1	0	1	1	1	97	151	
1	0	0	1	1	0	0	0	98	152	60
1	0	0	1	1	0	0	1	99	153	
1	0	0	1	1	0	1	0	9A	154	
1	0	0	1	1	0	1	1	9B	155	
1	0	0	1	1	1	0	0	9C	156	
1	0	0	1	1	1	0	1	9D	157	
1	0	0	1	1	1	1	0	9E	158	
1	0	0	1	1	1	1	1	9F	159	
1	0	1	0	0	0	0	0	A0	160	
1	0	1	0	0	0	0	1	A1	161	
1	0	1	0	0	0	1	0	A2	162	
1	0	1	0	0	0	1	1	A3	163	
1	0	1	0	0	1	0	0	A4	164	
1	0	1	0	0	1	0	1	A5	165	65
1	0	1	0	0	1	1	0	A6	166	
1	0	1	0	0	1	1	1	A7	167	
1	0	1	0	1	0	0	0	A8	168	
1	0	1	0	1	0	0	1	A9	169	
1	0	1	0	1	0	1	0	AA	170	
1	0	1	0	1	0	1	1	AB	171	
1	0	1	0	1	1	0	0	AC	172	
1	0	1	0	1	1	0	1	AD	173	
1	0	1	0	1	1	1	0	AE	174	
1	0	1	0	1	1	1	1	AF	175	
1	0	1	1	0	0	0	0	B0	176	
1	0	1	1	0	0	0	1	B1	177	
1	0	1	1	0	0	1	0	B2	178	70
1	0	1	1	0	0	1	1	B3	179	
1	0	1	1	0	1	0	0	B4	180	
1	0	1	1	0	1	0	1	B5	181	
1	0	1	1	0	1	1	0	B6	182	
1	0	1	1	0	1	1	1	B7	183	
1	0	1	1	1	0	0	0	B8	184	
1	0	1	1	1	0	0	1	B9	185	
1	0	1	1	1	0	1	0	BA	186	
1	0	1	1	1	0	1	1	BB	187	
1	0	1	1	1	1	0	0	BC	188	
1	0	1	1	1	1	0	1	BD	189	
1	0	1	1	1	1	1	0	BE	190	
1	0	1	1	1	1	1	1	BF	191	75
1	1	0	0	0	0	0	0	C0	192	
1	1	0	0	0	0	0	1	C1	193	
1	1	0	0	0	0	1	0	C2	194	
1	1	0	0	0	0	1	1	C3	195	
1	1	0	0	0	1	0	0	C4	196	
1	1	0	0	0	1	0	1	C5	197	
1	1	0	0	0	1	1	0	C6	198	
1	1	0	0	0	1	1	1	C7	199	
1	1	0	0	1	0	0	0	C8	200	
1	1	0	0	1	0	0	1	C9	201	
1	1	0	0	1	0	1	0	CA	202	
1	1	0	0	1	0	1	1	CB	203	

128	64	32	16	8	4	2	1	$	#	%
1	1	0	0	1	1	0	0	CC	204	80
1	1	0	0	1	1	0	1	CD	205	
1	1	0	0	1	1	1	0	CE	206	
1	1	0	0	1	1	1	1	CF	207	
1	1	0	1	0	0	0	0	D0	208	
1	1	0	1	0	0	0	1	D1	209	
1	1	0	1	0	0	1	0	D2	210	
1	1	0	1	0	0	1	1	D3	211	
1	1	0	1	0	1	0	0	D4	212	
1	1	0	1	0	1	0	1	D5	213	
1	1	0	1	0	1	1	0	D6	214	
1	1	0	1	0	1	1	1	D7	215	
1	1	0	1	1	0	0	0	D8	216	85
1	1	0	1	1	0	0	1	D9	217	
1	1	0	1	1	0	1	0	DA	218	
1	1	0	1	1	0	1	1	DB	219	
1	1	0	1	1	1	0	0	DC	220	
1	1	0	1	1	1	0	1	DD	221	
1	1	0	1	1	1	1	0	DE	222	
1	1	0	1	1	1	1	1	DF	223	
1	1	1	0	0	0	0	0	E0	224	
1	1	1	0	0	0	0	1	E1	225	
1	1	1	0	0	0	1	0	E2	226	
1	1	1	0	0	0	1	1	E3	227	
1	1	1	0	0	1	0	0	E4	228	
1	1	1	0	0	1	0	1	E5	229	90

128	64	32	16	8	4	2	1	$	#	%
1	1	1	0	0	1	1	0	E6	230	
1	1	1	0	0	1	1	1	E7	231	
1	1	1	0	1	0	0	0	E8	232	
1	1	1	0	1	0	0	1	E9	233	
1	1	1	0	1	0	1	0	EA	234	
1	1	1	0	1	0	1	1	EB	235	
1	1	1	0	1	1	0	0	EC	236	
1	1	1	0	1	1	0	1	ED	237	
1	1	1	0	1	1	1	0	EE	238	
1	1	1	0	1	1	1	1	EF	239	
1	1	1	1	0	0	0	0	F0	240	
1	1	1	1	0	0	0	1	F1	241	95
1	1	1	1	0	0	1	0	F2	242	
1	1	1	1	0	0	1	1	F3	243	
1	1	1	1	0	1	0	0	F4	244	
1	1	1	1	0	1	0	1	F5	245	
1	1	1	1	0	1	1	0	F6	246	
1	1	1	1	0	1	1	1	F7	247	
1	1	1	1	1	0	0	0	F8	248	
1	1	1	1	1	0	0	1	F9	249	
1	1	1	1	1	0	1	0	FA	250	
1	1	1	1	1	0	1	1	FB	251	
1	1	1	1	1	1	0	0	FC	252	
1	1	1	1	1	1	0	1	FD	253	
1	1	1	1	1	1	1	0	FE	254	
1	1	1	1	1	1	1	1	FF	255	100

Quick summary

Cable

The type of cable used is critical for reliable operation. It should either be one of the types listed on page 9, or a direct equivalent, or it should conform to the following requirements:

- For EIA485 (RS485) operation at 250k baud
- Characteristic impedance 85-150 ohms, nominally 120 ohms
- Low capacitance
- One or more twisted pairs
- Foil and braid shielded
- 24 AWG min. gauge for runs up to 300m (1000')
- 22 AWG min. gauge for runs up to 500m (1640')

Microphone cables and other, general purpose, two-core cables for audio or signalling use are not suitable for use with DMX512.

Problems due to incorrect cabling may not be immediately apparent. It is tempting to ignore the above advice as mic. cables do, indeed, appear to work fine. However, when used in a different environment, systems built with such cables may fail or be prone to random errors.

Use the right cable !

Connections

Connections should be made, wherever possible, by means of 5 pin XLR style connectors. The pin-out is the same at both ends and is as follows:

- Pin 1 Foil and braid shield
- Pin 2 First conductor of the first twisted pair
- Pin 3 Second conductor of the first twisted pair
- Pin 4 First conductor of the second twisted pair
- Pin 5 Second conductor of the second twisted pair

First, don't forget to pass the cable through the connector shell !

Separate the shield from the inner conductors and cut it back about 12mm (½"). Attach a short wire to the shield and solder to pin 1. Insulate any exposed shield strands and then solder the remaining 4 inner conductors.

Fit an insulator or PVC tape around the outside of the group of five pins. It is important to prevent the connector shell from contacting any of the pins, including the shield.

The second pair, on pins 4 and 5 is optional and is not required in basic DMX512 systems. Nevertheless, it is advisable to fit a 2-pair cable, with all the pins connected, wherever possible.

<u>Termination</u>

The termination is a 120 ohm ¼watt resistor fitted across pins 2 and 3 at the end of the line furthest from the transmitter.

<u>*Termination must be fitted in all DMX512 installations*</u>

Termination checklist:

- The line should start at the console and link to device 1, then to device 2 and so on. The last device should link the line to the terminator resistor.
- Termination resistor should be 90 - 150 ohms approx. The optimum value is 120 ohms.
- Termination must be applied once only at the far end of the line.
- Only pins 2 and 3 are connected to the termination resistor.
- Some devices feature a 'termination', 'end-of-line' or 'last-rack' switch. When many such devices are connected to the line it is most important to check that only the last device on the line has its switch set.
- A common terminator is a line male XLR connector with the resistor fitted inside. This 'dummy' plug is connected to the output of the last device on the line.

DMX512 line routing

- DMX512 lines can only be run as a daisy-chain. The line jumps from the console to one device and then to the next device and so on.
- Only 32 devices may be connected to one line.
- Devices may be connected to the line at any point along its length

DMX512 lines cannot be split into branches by making up simple 'twofer' adapter leads (Y cords).

If DMX512 signals must be sent in different directions then you must use a splitter amplifier. The amplifier will require a separate output for each branch that you need to provide.

Lines fed from splitter amplifiers must all be treated individually as new DMX512 lines. Each will require a termination resistor at the far end. Each will be subject to the same limit of a maximum of 32 devices.

Physical layout

The EIA485 medium used by DMX512 is very robust. However, it is worth taking extra care with your cable routing:

- Avoid long parallel runs with power cables.
- Avoid dimmer load cables wherever possible.
  (Crossovers of power and load cables are acceptable)
- Avoid locations where the cable may degrade over time. Alternatively, choose a suitably resistant cable.
- Use a strong cable and provide adequate support. Some cables are fitted with a core of high-tensile fibres.
- If the cable is likely to come into contact with hot objects, such as luminaires, choose a type with either PTFE, FEP or Polyurethane jacket.

Isolation

The EIA485 system, by which DMX512 signals are sent, can in some circumstances suffer from problems due to equipment grounding. This effect is similar to the 'hum loop' problem with audio equipment when multiple units are connected to mains ground.

If the grounds of all the devices are not at exactly the same potential (voltage) then a current may flow down the shield between devices. This current, if large enough, can cause errors and exceptionally, destruction of DMX512 transmitters and receivers.

In small systems this is most unlikely to be a problem. In larger systems it is advisable to isolate some, or all of the devices from each other and/or from the console.

It is strongly recommended that optical isolation is fitted where practical or that devices are chosen that feature built-in optical isolation.

It is easy to isolate devices by means of an opto-isolator amplifier. These are available from many manufacturers of DMX512 equipment throughout the world.

Identification of isolated equipment can be carried out by means of a continuity tester:

- Measure the resistance between pin 1 of a device's input connector and the mains ground for that device. If the measurement shows open-circuit, or very high resistance then the device is isolated.

See page 37 for more details of tests for ground-loops (common mode voltage tests) and isolation.

Useful Addresses:

PLASA Ltd.
7 Highlight House
St Leonard's Road
Eastbourne
East Sussex BN21 3UH
United Kingdom

USITT Inc.
10 West 19th Street, Suite 5A
New York, NY 10011-4206
U.S.A.

ELECTRONIC INDUSTRIES ASSOCIATION (EIA)
2001 Eye Street, N.W.
Washington D.C. 20006
U.S.A

BELDEN WIRE AND CABLE
P.O Box 1980
Richmond
IN 47375, USA.

ALPHA WIRE CORPORATION
711 Lidgerwood Ave
PO Box 711
Elizabeth
NJ 07207, USA

TMB ASSOCIATES (Proplex cables)
2102 W. Kenmere Ave
Burbank
CA91504, USA.