DMX 512 Explained. Part 1

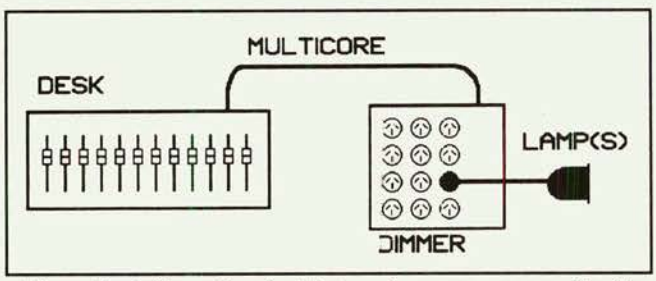
By Gary Pritchard

What is DMX-512?

The DMX 512 lighting control protocol is a standard published by the United States Institute of Theater Technology (USITT) that describes a method of digital data transmission between controllers and dimmers. The D in the name stands for 'digital', the 'MZ for 'multiplex' and the '512' represents the number of channels or dimmers that the system can handle, namely five hundred and twelve.

The unravel all of this, you first need an understanding of what constitutes a digital system and what is meant by 'digital data transmission'.

If we look at the history of lighting control systems we find that after the invention of the thyristor controlled dimmer, the basic arrangement of a lighting control system has not changed a great deal. A typical modern system would comprise of a control desk located at the rear of the auditorium for preference, and interconnecting cable, and a bank of dimmers.



The method of operation for this type of system is that the lighting desk generates a control signal relative to the position of the fader on the desk. This signal is then conveyed via the interconnecting cable to the dimmers, whose job it is to use this signal to regulate the amount of voltage or power fed to the lamp. i.e. control the lamp's intensity.

It is in the method of conveying the information from the control desk to the dimmer that the DMX-512 specification refers to and is of interest to us in this particular discussion.

Typically most of you will be aware of what is termed an analog system. In these systems the position of the fader is translated into an electrical signal that varies between 0 volts (usually representing lamp off) and 10 volts (usually representing lamp full intensity). If the fader is at some intermediate position between 0% and 100% - say 47% - then this is converted into the equivalent percentage of control voltage; in this case 4.7 volts.

An alternative method or technique to an analog signal is what is termed a digital signal. A digital signal does not take on various voltage levels to represent the fader position, but rather uses a combination of two discrete states to represent the desired level.

The best way to explain this concept is with an example: Everyone is well aware that a light switch has two discrete states, ON and OFF - and in it's simplest form this is effectively digital control. However, it is a little difficult to get a smooth 2 minute fade with this type of system.

Instead, suppose that we employ electronics such that when the switch is turned on the lamp does not go to full, but rather to a selected percentage of full. Furthermore if we were to use two switches, name them S1 and S2 for the sake of the discussion, and arrange the electronics such that turning S1 on will increase the intensity by only 66.6% and turning S2 on will increase the lamp intensity by only 33.3%, then as you can see in the following table, we can use a combination of these switches to give four different light levels.

State	S1 (66.6%)	S2 (33.3%)	Intensity
1	OFF	OFF	0%
2	OFF	ON	33.3%
3	ON	OFF	66.6%
4	ON	ON	100%

If we take this idea a step further by increasing the number of switches to 3 and changing the relative percentage added by each switch, then we have eight possible levels of light that can select. Again this is shown in the table below:

State	S1 (57.14%)	S2 (28.56%)	S3 (14.28%)	Intensity
1	OFF	OFF	OFF	0%
2	OFF	OFF	ON	14.28%
3	OFF	ON	OFF	28.56%
4	OFF	ON	ON	42.86%
5	ON	OFF	OFF	57.14%
6	ON	OFF	ON	71.42%
7	ON	ON	OFF	85.17%
8	ON	ON	ON	100.0%

Still with even eight states, a smooth fade would be impossible. However, extending the idea to eight switches gives us a total possible combination of 256 states and hence a resolution of about 0.39%. That is a combination of eight discrete states, enabling us to specify a level on the dimmer to 0.39% accuracy.

To put what I have just described into engineering terms, the state of each switch in termed a 'bit' of information, and the combination of eight bits is termed a 'byte'.

Therefore, rather than sending an analog voltage to the dimmers to specify the light level required, we could instead send the state of our eight switches. Our dimmer could then interpret these eight bits of information and set our lamp level accordingly. Why should we want to do that? What's wrong with the old analog system?

There are a number of reasons for choosing digital technology over analog. Firstly almost all control desks utilise a microcomputer of one form or another. It just so happens that these computers operate purley on discrete levels (notionally OFF or ON) and hence sending a set of discrete states to a dimmer is easier than first converting the internal discrete or digital levels into an analog level to send to the dimmers.

Secondly, more dimmers are now using microprocessor technology, so again it is easier if the dimmer can receiev digital input, rather than having to convert an analog signal for its own use.

Continued next month.

DMX 512 Explained. Part 2

By Gary Pritchard

What is DMX-512?

Thirdly, in electronic terms it is more reliable to transmit a discrete or digital signal than an analog one since the dimmer need only decide whether the state is off or on rather than if it is 5.0 Volts or 5.1 Volts.

A perfect example of this is the modern CD verses the LP record. The LP operates as an analog system since the sound reproduced depends on the relative movement of the needle, whereas the CD is recorded in a digital format that is read by a laser inside the player. I am sure you would all prefer to have the quality of the CD as opposed to the LP.

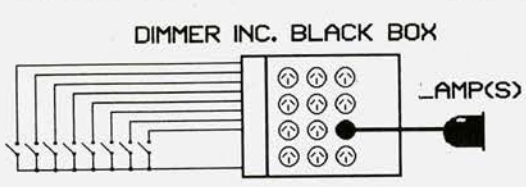
As an aside to this you would also notice that the LP record is subject to a lot of noise (crackles and pops) however the CD is virtually noise free. This holds true for our lighting system as well; the digital system is less prone to interference or noise than its analog counterpart.

This is not such a large concern when the desk and dimmer are both within a few metres of each other but is of great advantage if they are separated by some 50 or 100 metres.

Nevertheless, it should also be borne in mind that just as a scratched CD will not reproduce correctly our digital signal is not necessarily bomb proof.

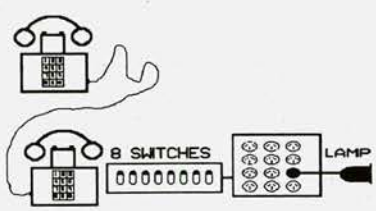
SERIAL COMMUNICATION:

Now to convey the state of our switches (our byte of information) from the controller to the dimmer, we could use one wire for each switch thus requiring at least nine wires for every dimmer we wished to control.



This doesn't appear very attractive and again electronics can be used to our advantage. What in fact is used is a technique called serial communication. What happens here is that the dimmer is first told that the state of the switches is about to be sent. Then the state of each individual switch is transmitted one after the other in a pre-defined order.

To draw a parallel; imagine two people on a telephone line. The person transmitting the information could convey the state of the switches by the words "START, (which off course indicates to the receiver that the information is about to be sent) OFF,OFF,ON,ON,OFF,OFF,ON,OFF,STOP". The person receiving this would then be able to interpret these and set the dimmer level accordingly.

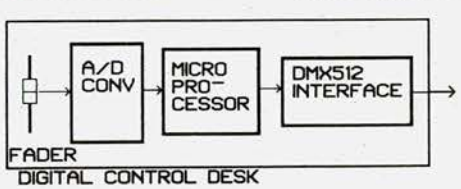


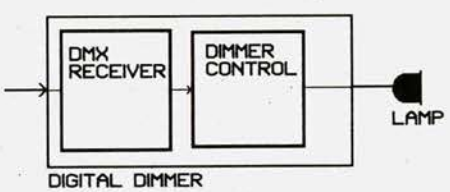
Obviously electronics is able to carry out the task much faster than two people on the telephone and to give you an idea of the speed involved, DMX512 would convey the above information in about 44uS. That is; about 44 millionths of a second.

Thus using serial communication we can get back to two wires per channel.

Naturally enough in the lighting control desk we want to use a fader and not switches to set the level of the lamp. To achieve this the control desk contains an Analog to digital converter (or A/D converter) to first convert the position of the fader into our desired digital representation of eight states.

So our control system now looks like this:





MULTIPLEXING:

We have seen that it is possible for us to convey the desired level of the lamp to the dimmer in a very short time. It seems fairly ludicrous therefore for the controller to tell the dimmer every 44uS what level we want the lamp to be. There is no way that the intensity of the lamp could alter appreciably in such a small amount of time.

What if we were to only send the level of the lamp to the dimmer say once every milliSecond (mS) (thousandth of a second) This would still be faster than the lamp could visually respond (in actual fact even faster than the average dimmer could respond but that's another story).

If we choose to do this we are now only utilising the wires between the controller and dimmer for only a small percentage of time; 44uS every 1mS. So instead of letting the line sit idle and doing nothing for most of its life, we have another option. That is to use the spare time to send the level of other channels down the same wires.

This is in fact the technique used in DMX512 and the engineering term for such a technique is "Time Division Multiplexing" or simply multiplexing for short.

In DMX512 up to a maximum of 512 dimmer levels can be sent down the same pair of wires. This results in the level of each dimmer being updated approximately once every 22mS or about 44 times per second. This is considered to be a practical limit or perhaps more a compromise between the number of channels we can send down the line and the update rate of each channel. In practice it has been found it to be a good compromise.

Continued next month.

Gary Pritchard is the owner of LSC Electronics, an Australian Lighting Control manufacturer, based in Melbourne.

DMX 512 Explained. Part 3

By Gary Pritchard

What is DMX-512?

SERIAL COMMUNICATION *(continued)*

So recapping all of that we can now explain that DMX512 is a standard that specifies **D**igital **M**ultiple**X**ing for transmitting up to 512 dimmer levels down a single pair of wires. As well as the electrical specification, the DMX512 standard also includes definitions of the type and sex of connector and the pin connections that must be used.

It should be noted however that DMX512 is only one standard for doing this. Other standards for doing the same thing exist from various manufacturers. The bonus of DMX512 is that it is specified by an independent international body that makes no monetary or political gains from its specification or use. The standard was formulated and is monitored by an international collection of 32 committee members (of which I am one) that hail from various sections of the industry. These include manufacturers, lighting designers, specifiers and rental company operators. This makes the standard truly international.

PRACTICAL APPLICATION:

Having this cable that now has up to 512 dimmer levels being sent down it, how does any dimmer know which levels belongs to it and which don't? The electronics inside the dimmer has the ability to pick out any of the dimmer levels that it desires but we need a way to tell it which ones to use.

This is usually achieved by using what are termed address switches. These switches tell the dimmer which channels in the DMX512 data stream that it should use for its control.

In the case of LSC product, we use three switches on our digital products that can be set to select any starting address or channel number. Therefore if we selected 147 on these switches the first circuit on this dimmer would respond to dimmer level 147 on the DMX512 cable, the second to 148, the third to 149 etc.

Other manufacturers may do their dimmer addressing in a slightly different manner. What they provide is a set of switches that specify a dimmer pack starting number. Thus dimmer pack number one will respond to channels 1 through to 12 on the DMX512 cable; Dimmer pack 2 will respond to channels 13 to 24, etc. I don't believe this system is as flexible as ours but it is certainly a valid way of doing it.

A common situation arises when people are considering new equipment and would like to take advantage of DMX512. We often get the question "I have to replace my control desk but the dimmers I own are working fine and I don't want to (can't afford to) replace them. Can I buy and use a desk with DMX512 output"? The corollary to this is of course "I need new dimmers but I only bought the desk last year and it only gives an analog output. Can I buy DMX512 dimmers". As there are a large number of these type of situations existing the basic problem is to be able to convert from analog to digital or from digital to analog.

The answer to these questions is yes. Products do exist that will convert from analog to digital and vice versa. When converting from analog to digital the product is termed a Multiplexer and when converting from digital to analog it is known as a De-multiplexer.

We make a product called the LINKLIGHT that performs these functions. Although the front panel says it is a multiplexer the Linklight in-fact is switch selectable to be a multiplexer or a de-multiplexer. Again address switches are used on this product for address selection.

ADVANTAGES OF DMX512:

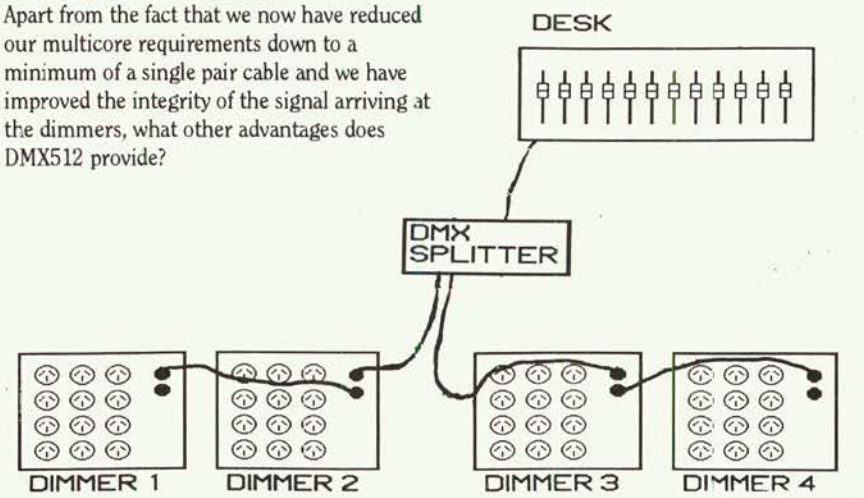
Apart from the fact that we now have reduced our multicore requirements down to a minimum of a single pair cable and we have improved the integrity of the signal arriving at the dimmers, what other advantages does DMX512 provide?

(1) Ablilty to parallel dimmers easily. It is fairly common in a lot of situations to run lamps in pairs one on each side of the stage. To achieve this we can run a 240 Volt cable from one side of the stage to the other and connect the two lamps into one dimmer circuit.

Alternately, we could place two dimmers, one on each side of the stage, and if they were analog dimmers, make up an ugly multicore to connect the two.

However if they were digital dimmers or analog dimmers and demultiplexers, all we need to do using DMX512 is to connect the dimmers onto the same DMX512 line and select the same address on both dimmers or demultiplexers.

(2) Distributed dimming. Consider the problem of lighting in a large arena. Here the best alternative to use is to distribute the dimmer racks around the arena in the locations that they are needed. If we used and analog system, the analog multicore wiring would be a nightmare. However, with a DMX512 approach the interconnection is simple. This is exactly what happened for the Opening and Closing ceremonies of the Commonwealth Games in Auckland last year. The lighting system set up and operated by Selecon, consisted of a control desk, a DMX512 splitter and two 1km DMX512 cable runs heading in opposite directions around the arena.



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DMX 512 Explained. Part 4

By Gary Pritchard

What is DMX-512?

ADVANTAGES OF DMX512: (continued)

(3) Softpatching. One of the bugbears of lighting systems in the past has been the laborious task of patching. Two types of patching systems have generally been and still are used in analog systems. These are the hot-patch which is done at the mains or 240 Volt end of things and pin-patching where the analog signal out of the desk can be routed to the desired dimmer(s) by the use of a pin patch board.

One of the offshoots of digital systems is that a feature known as softpatching has become feasible. Since we already have our control signal in a digital format which is easily handled by a computer and with DMX512 we have the capability to send levels to any number of dimmers up to 512 with no cost or hardware increase, softpatching becomes an easy task. What softpatching provides is the ability to connect a desk channel to any number or combination of dimmers. The "soft" in softpatching comes from the fact that these connections can be easily changed at the operator's whim.

I don't really intend to cover all the benefits of softpatching in this discussion but if anyone is interested please feel free to contact me for further details.

PROBLEMS WHEN USING DMX512

OK so what you're probably thinking is "This is great I get all these channels down the equivalent size of a microphone cable and all these great features" but wait a minute where's the catch? Fortunately in the case of DMX512 there is not a big price to pay but it still obeys the golden rule - there's no such thing as a free lunch!

So what are the possible pitfalls when using DMX512?

Possibly the least understood problem that is encountered when using DMX512 is that special precautions must be taken when interconnecting equipment. DMX512 uses some very fast electronic signals and these signals are very particular about the type of cable they are given to travel along. They get more particular as the length of the cable is increased.

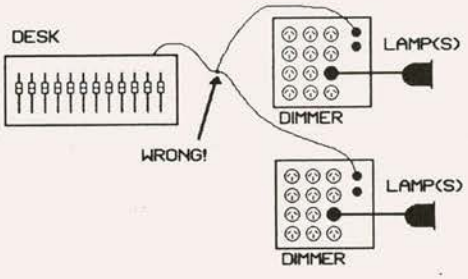
The first and foremost trap to avoid is not to use low quality cable for DMX512 signals. The common thing to do is to use microphone cable and over short distances, although we will never recommend it, this should work fine. However if you value your show and the desk and dimmers are separated by more than several metres then invest in a good quality data cable. Don't forget that with the old analog systems you were prepared to invest thousand of dollars in a multicore so why skimp on a good quality DMX512 cable?

If you are using a fairly long multicore and by that I mean over say 50 metres then it is wise to use what is called a terminator (more affectionately known at LSC as a "Schwarzenegger"). A terminator is merely a resistor connected across the end of the line. It is needed to prevent reflections on the line which would confuse the dimmers.

Drawing a simple parallel again, consider a swimming pool. If you drop a stone into the centre of the pool ripples will start moving toward the edge of the pool. You will probably have noticed that after the ripple or wave reaches the wall of the pool it turns around and starts heading back toward the centre of the pool.

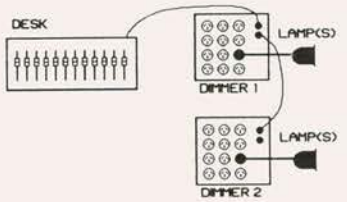
The same occurs in the DMX cable. When the signal reaches the end of the cable, if it has no where to go then it will turn around and head back up the cable. This is very confusing to the dimmers since the reflection will interfere with the real signal and the dimmers do not know which one to believe.

A terminator eliminates this problem by soaking up the signal when it reaches the end of the cable thus preventing reflections.

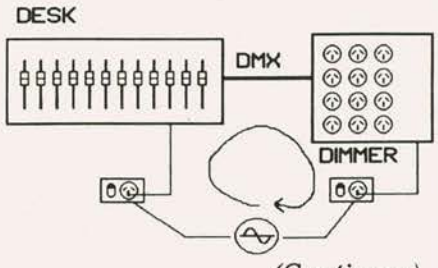


Extending this idea a little further, what the signal really wants to see once it leaves the desk (transmitter) is one continuous piece of cable. The terminator fools the signal into believing that the cable goes forever.

Here the signal coming along the cable will see a difference at the junction of the two legs and will complain bitterly by giving a reflection from this point back up the line. A better way to run the cabling for this is as shown here; first to one dimmer and then to the second not forgetting your terminator at the end of the line. DMX512 is specified to 1km. so there will be few occasions that will violate this. If a longer cable run is required, then a repeater should be used.



EARTH LOOPS - Earth loops are again a very little understood problem and are generally associated with audio equipment. This problem arises when both the dimmers and the desk have their common signal tied to the mains earth. If the earth potential differs at the two points where the respective equipment is plugged in, large earth currents flow between these points via the common wire in your DMX512 cable. This again creates havoc for the digital signals and error can be introduced.



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DMX 512 Explained. Part 5

By Gary Pritchard

What is DMX-512?

EARTH LOOPS (continued)

It is thus essential for good signals that the system common should only be connected to mains earth at only one point at most. At LSC we take the approach of isolating the common wire in both our dimmers and desks from mains earth thereby eliminating any potential problems. Other manufacturers do not do this and if you are using multiplexers or demultiplexers the problem can sneak into the system. It is one to watch for and if in doubt, speak to the manufacturer of the equipment for clarification.

CONTROL RESOLUTION:

One of the more recent criticisms of DMX512 is that it does not provide enough resolution. We saw before that using 8 bits of information gives us a resolution of 0.39%. For the majority of cases this is more than adequate, however some people are now starting to use DMX512 for things other than controlling dimmers. Things such as colour scrollers. Here our resolution on an 11 gel scroll is only 35mm or 1.5". Also there is a plethora of moving light systems that could possibly be controlled by a DMX512 signal but the resolution is just not sufficient to be able to position the fixture accurately enough for these systems.

One can take two possible views on this argument. DMX512 should be adapted to provide control for these products or alternatively it should be left alone since its original scope as stated in the standard is for the "transmission of data between controllers and dimmers".

DMX512 has the scope to be modified to communicate with alternative devices however it seems that everyone is more than happy to leave well enough alone. At recent DMX512 committee meetings, the last of which was in Boston in February 1991, there was a clear majority among those members present that the DMX512 specification should be left as it is.

CONCLUSION

Therefore looking down the road a little, it is not too hard to see that we as an industry will require some means of being able to control moving fixtures, colour scrollers, dimmers and who knows what else, preferably from one central operating point. A number of people have put forward proposals to solve this problem but at this stage no one system has been accepted. There will certainly be a new standard, but who will propose it and when is yet to be seen.