

**DMX 101:
A DMX 512 HANDBOOK**

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1. Introduction to DMX

This handbook is designed to promote basic understanding of the DMX 512 protocol, including theory of operation, proper equipment use, and some basic application examples.

DMX is an acronym for **D**igital **M**ultiplex, a communication protocol (a set of rules) used to remotely control lighting dimmers and intelligent fixtures. It is designed to provide a common communications standard between these lighting devices regardless of the manufacturer.

The 512 after the DMX refers to the number of control channels used on one network segment (often called a ‘universe’) of devices. In a simple dimming system, one channel controls the intensity of one dimmer. A single intelligent fixture, however, may require several channels to control its various parameters (one channel each for pan, tilt, color, gobo, etc.).

A basic dimming control console (such as the 16 channel Elation Stage-Setter 8) may support only a few of the 512 available channels. Many professional control consoles (such as the 3 universe, 1536 channel Elation Show Designer 3) support multiple universes, allowing for thousands of control channels.

The topics this handbook will cover are:

- Industry Standards
- Theory of Operation
- Protocol Specifications
- Sample Applications

2. Industry Standards

About 20 years ago, most manufacturers used their own, proprietary control protocols. This forced system designers to use only fixtures and control consoles from the same manufacturer. There was no control standard to allow the use of different products.

A standard is a set of widely agreed-upon guidelines for interoperability at both communications and mechanical levels. Standardization of protocol and equipment provides many benefits to manufacturers and end users. These benefits include:

- Increased product quality and safety
- Reduced development time and cost
- Sound engineering practices
- Protection against obsolescence

The following organizations have developed standards that relate directly to the DMX 512 protocol:

- USITT
- ESTA
- ANSI
- EIA/TIA

2.1 USITT

The United States Institute of Theatre Technology (USITT) supports, develops, and promotes a wide variety of standards for the theatrical and entertainment industry. In 1986, USITT developed the DMX 512 protocol as a simple, flexible, and reliable standard for lighting control.

In 1998, USITT transferred maintenance of the DMX 512 protocol to the Technical Standards Program of ESTA. The standard is constantly revised and updated as technology continues to advance.

2.2 ESTA

The Entertainment Services and Technology Association (ESTA) is a non-profit trade association representing the entertainment technology industry. ESTA promotes professionalism and growth in the industry and provides a forum where interested parties can come together to exchange ideas and information, create standards and recommended practices, and address issues of training and certification.

2.3 ANSI

The American National Standards Institute (ANSI) is an organization composed of representatives from industry and government that collectively determine standards for the electronics industry as well as many other fields, such as chemical and nuclear engineering, health and safety, and construction. ANSI also represents the United States in setting international standards. New electronic equipment and methods must undergo extensive testing to obtain ANSI approval.

In 2004, ANSI approved the DMX 512 standard, and has since approved several other related standards including Remote Device Management (RDM) and Architecture for Control Networks (ACN). The actual standards are listed below:

- ANSI E1.11-2004 - Entertainment Technology USITT DMX512-A - Asynchronous Serial Digital Data Transmission Standard for Controlling Lighting Equipment and Accessories
- ANSI E1.20 - Entertainment Technology RDM - Remote Device Management over USITT DMX512
- ANSI E1.17 - Entertainment Technology ACN – Architecture for Control Networks (Multipurpose Network Control Protocol Suite)

2.4 EIA/TIA

The Electronics Industry Alliance (EIA) is a trade organization composed of representatives from electronics manufacturing firms across the United States. EIA began in 1924 as the Radio Manufacturers Association (RMA), and has grown to include manufacturers of televisions, semiconductors, computers, and networking devices. The group sets standards for its members, helps write ANSI standards, and lobbies for legislation favorable to growth of the computer and electronics industry.

The EIA is composed of several subgroups including the Telecommunications Industry Association (TIA). The EIA/TIA-485 standard is the communication basis for DMX 512.

2.5 References

For more information on any of these organizations or standards, visit their websites:

- www.usitt.org
- www.esta.org
- www.ansi.org
- www.eia.org

3. Theory of Operation

DMX 512 is an asynchronous serial digital data protocol. While that might mean something to an engineer, most people are not familiar with how all this techno-gibberish actually accomplishes lighting control. This section will attempt to explain how DMX operates in a simplified and easy-to-understand manner.

The topics this section will cover are:

- The Cable TV Analogy
- DMX Communications

3.1 The Cable TV Analogy

A central concept of DMX 512 is the ability to transmit data on multiple channels over a single cable. To better understand this concept, imagine a simple cable TV system (Figure 1) with four major components:

- Cable TV Company
- Cable
- Decoder
- TV

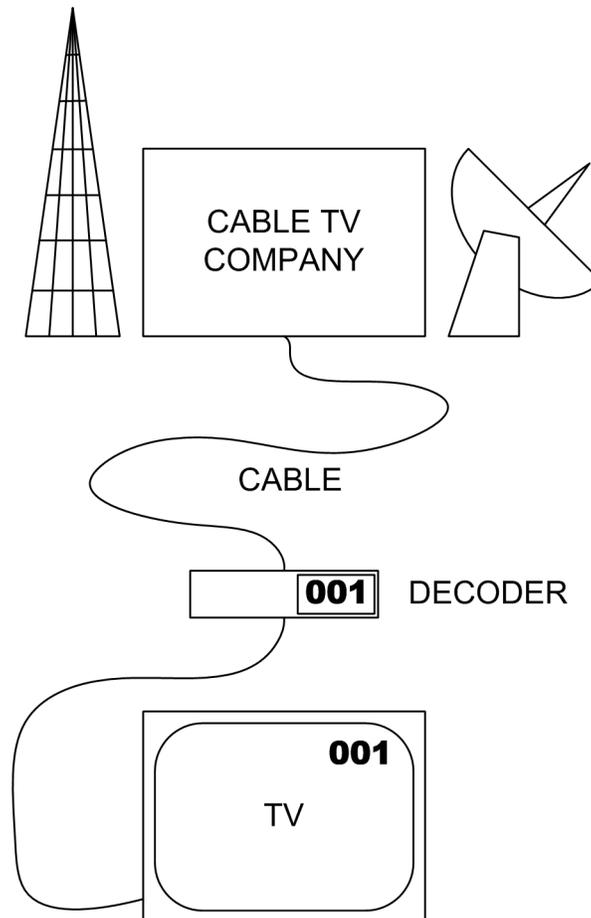


Figure 1

The Cable TV Company broadcasts many channels at once in a mixed signal over a single cable. The Cable carries the signal to a Decoder, usually a cable TV box or similar device. The Decoder is able to separate all the channels from one mixed signal, and send only the desired channel to the TV (channel 001, in this example), ignoring the rest.

Now imagine a simple DMX system (Figure 2), where:

- The Cable TV Company is the DMX Control Console
- The Cable is the DMX Cable
- The Decoder is the DMX Decoder (built into a Dimmer)
- The TV is the Lighting Fixture

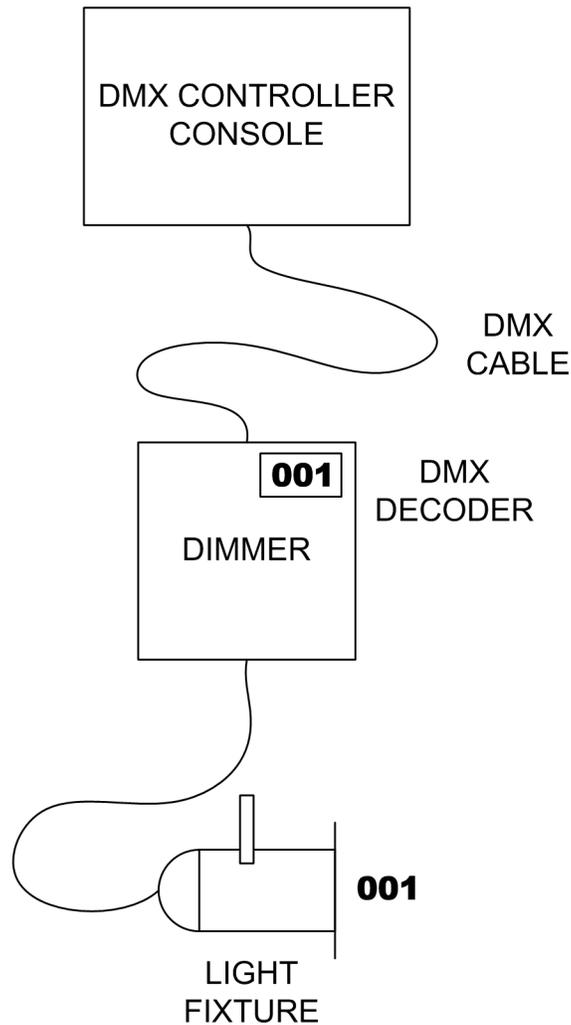


Figure 2

The DMX Control Console will broadcast up to 512 channels over one DMX Cable. Some of these channels may not be used, but will still be transmitted, as required by the protocol. The Decoder in this example is built into the Dimmer. It must be set to a desired channel (channel 001, in this example) to control the connected Light Fixture. This is usually accomplished using a DIP switch or LED/LCD display. This desired 'channel' is commonly known as the DMX address.

Many DMX devices (such as dimmers and intelligent fixtures) are capable of receiving several control channels at once. If a Dimmer has four channels capable of controlling four Light Fixtures (Figure 3), it must know which four control channels to receive. This is accomplished by setting a 'base address', or the DMX address for the first Light Fixture (channel 005, in this example). The remaining Light Fixtures will be controlled by the next three sequential control channels. The DMX Decoder knows it needs only these four control channels, and will ignore the rest.

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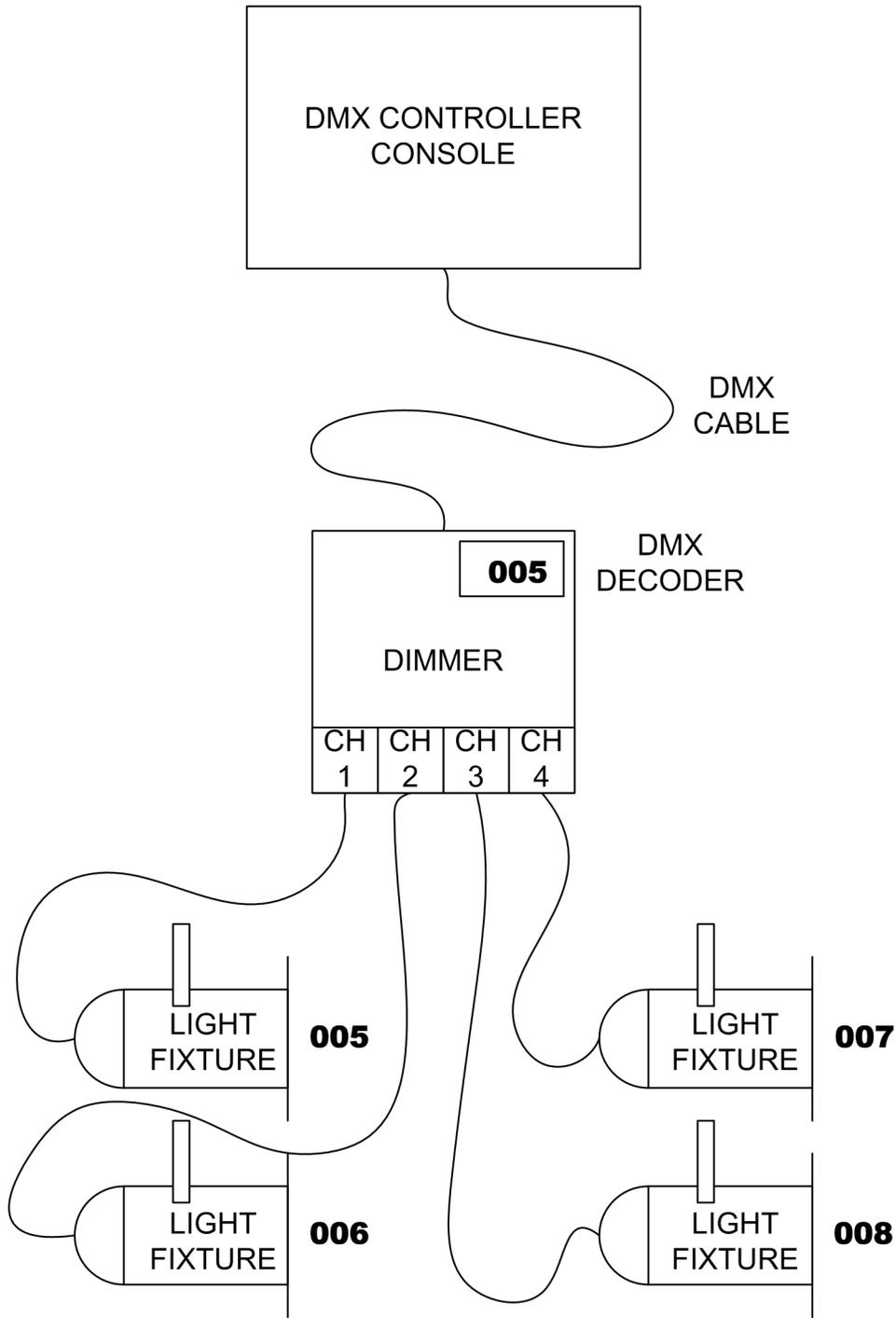


Figure 3

3.2 DMX Communications

In the world of digital communications, information is sent using precise electrical voltage pulses. A positive voltage pulse represents a 1. A zero voltage pulse (or no voltage) represents a 0. Systems using 1's and 0's to encode information are called binary systems.

Each pulse in a digital signal is called a binary digit, or bit. A bit can only have one of two values, 1 or 0. A grouping of eight bits, called a byte, is used to carry one piece of information. This 'information' is simply a value ranging from 0 to 255.

The most common method of transmitting digital signals is to send data one bit at a time in one direction over one wire. Since each bit is transmitted in series, this method is known as Serial Communication. In its simplest form, Serial Communication requires one data wire for transmission and one common reference (or ground) wire.

There are two types of Serial Communication:

- Synchronous
- Asynchronous

In Synchronous data transmission, data is sent as a group of characters in a single stream of bits known as a bit-stream. For this method to work, timing devices at both ends must be in perfect synchronization, requiring precision equipment at a higher cost.

In Asynchronous data transmission, data is sent one byte at a time. Asynchronous devices do not require perfect synchronization, but their timing signals must be close (within about 5%). This method is relatively simple, and therefore inexpensive.

There are many standards for Serial Communications, each having its own advantages and disadvantages. Communications standards generally fall into two broad categories:

- Single-ended (unbalanced)
- Differential (balanced)

The single-ended specifications allow for data transmission from one transmitter to one receiver at relatively slow data rates and short distances. When communicating at high data rates, or over long distances in real-world environments, single-ended transmission methods are often inadequate. Differential data transmission offers superior performance in most applications by helping to nullify the effects of interference on the signal. This is achieved by using two wires to transmit the signal (with opposing polarity) instead of just one.

The DMX 512 protocol is based on the EIA/TIA-485 standard (commonly known as Recommended Standard 485 or RS-485), which uses asynchronous, differential data transmission. This standard supports 32 devices on one network at a distance of up to 4000 feet. One device functions as the master (the DMX controller) on a network, while the rest function as slaves (dimmers, intelligent fixtures, etc.). Only the master transmits over the network, and all slaves receive the same data.

While 4000 feet may be specified by the standard, most manufacturers recommend DMX runs of no more than 1000 feet (300 feet between devices) before using a repeater to regenerate the signal. Each device should have input and output connectors, but these are usually wired together. No re-transmission or amplification is performed.

Devices are connected in a daisy-chain fashion, from the controller to device #1, then device #1 to device #2, and so on. The final device in the daisy-chain must be terminated. The terminator absorbs signal power which would otherwise be reflected back into the cable and degrade the data. A terminator simply places a 110-120 Ohm, 0.5 Watt resistor across the two transmission wires.

NOTE: DMX cannot be split reliably by making Y-cables or T-connectors. DMX splitter/repeaters (such as the Elation Opto Branch 4) typically use optical isolation to protect each segment from electrical faults on other branches. These can be used to increase the number of devices on one network beyond the limit of 32. Each branch of a splitter/repeater can support up to 32 devices.

3.3 Summary

So how does all this information relate to controlling a light fixture? Think of it in terms of the simple DMX Controller Console (Figure 4). The console may have up to 512 control faders on it (8 in this example). Each fader controls the intensity of one light (using one DMX Channel). The position of the fader represents an 8-bit value (DMX Value) between 0 and 255, where 0 is off and 255 is full on.

Up to 32 devices may be connected in a daisy-chain, with a terminator on the last device. Using a DMX splitter/repeater (opto-isolator) can extend both cable distance (as the signal is regenerated and re-transmitted) and the number of devices (up to 32 per branch).

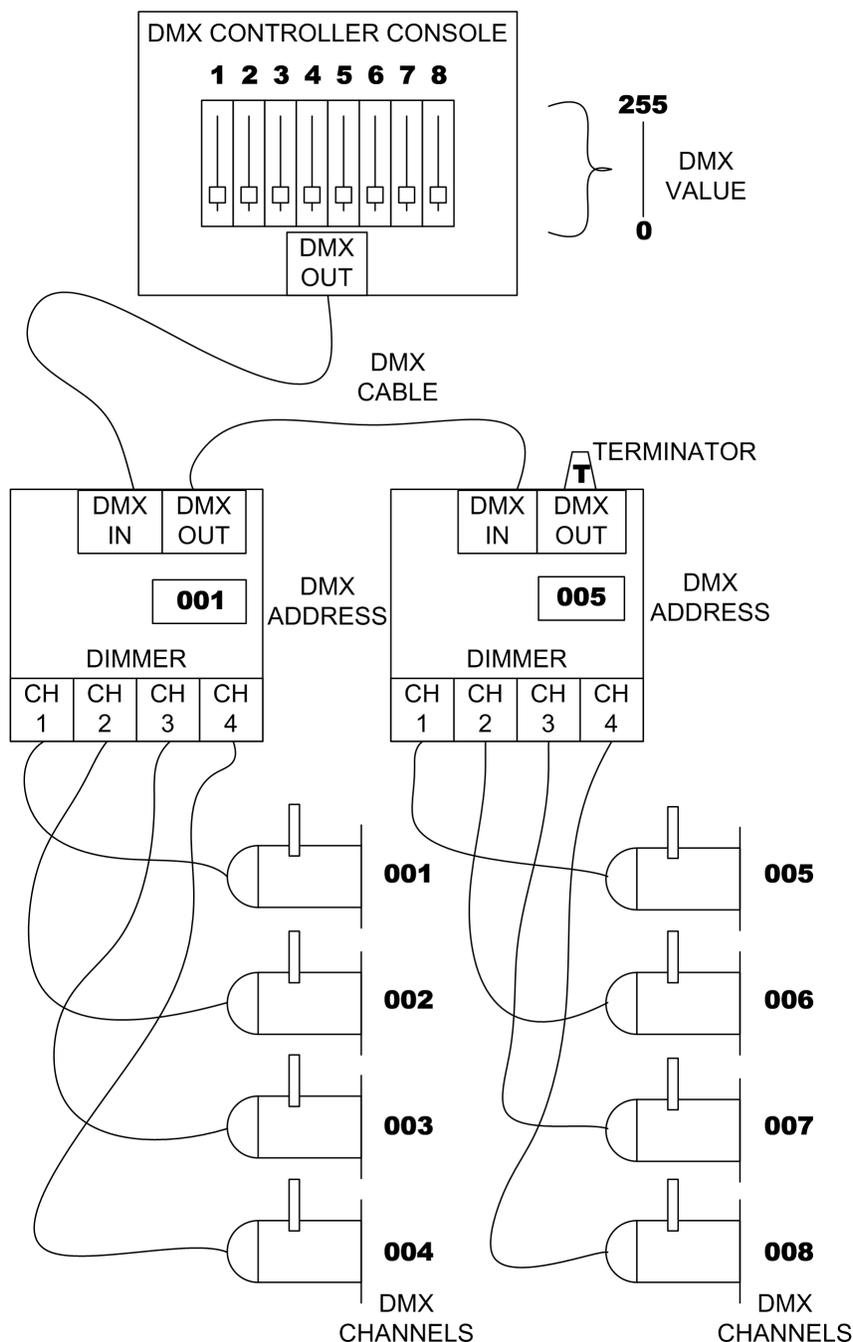


Figure 4

4. Protocol Specifications

Understanding how DMX 512 operates is important, but it's only part of the picture. The physical equipment, connectors and cabling, play a critical role in the proper functionality of the protocol. The DMX standard specifies exactly what types of connectors and cable may be used.

It is also important to understand the logic behind the data that is transmitted. Data is sent in a specific manner so that the receiver can correctly translate it into action.

The topics this section will cover are:

- Connectors
- Cabling
- Data

4.1 Connectors

The DMX standard specifies 5-pin XLR connectors (Figure 5). The name comes from the original manufacturer (Cannon **X** connector, with a **L**atch and **R**ubber guard). Only three of these pins have standardized use however, leading many companies to make use of inexpensive and readily available 3-pin XLR connectors (Figure 6). The remaining two pins are in place for future use, such as allowing connected devices to communicate information back to the controller (lamp hours, operating temperatures, etc.).

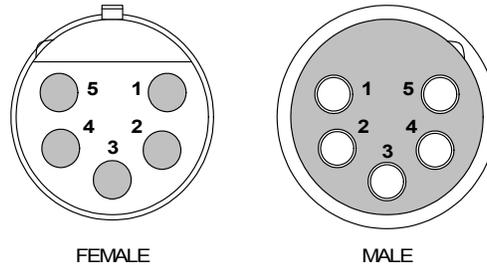


Figure 5

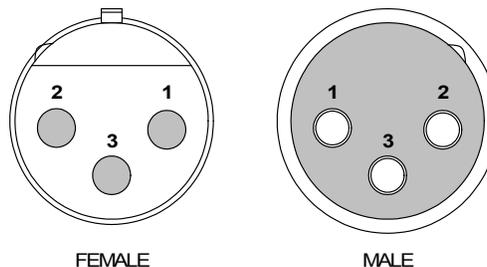


Figure 6

Table 1: DMX 512 Connector Pinout

Pin	Wire	Signal
1	Shield Drain	Ground / 0V
2	Inner Conductor (Black)	Data -
3	Inner Conductor (White)	Data +
4	Inner Conductor (Green)	Data - (Spare)
5	Inner Conductor (Red)	Data + (Spare)

NOTE: Many manufacturers use pins 4 and 5 for non-standard applications, often using voltages that are potentially dangerous to DMX compliant devices. Such applications are meant only for use with approved devices (usually from the same manufacturer). Use with standard DMX devices can cause serious damage to equipment.

4.2 Cabling

Standard DMX 512 requires twisted-pair, shielded, low-capacitance data cable (Figure 7) designed for RS-485 (such as ACCU-Cable from Elation). The twisted-pair configuration ensures that any interference affects both signals equally. This practice is common to good data cable, helping the signal driver eliminate any interference. The cable shield also protects against interference. A shield 'drain' wire makes connector installation easier.

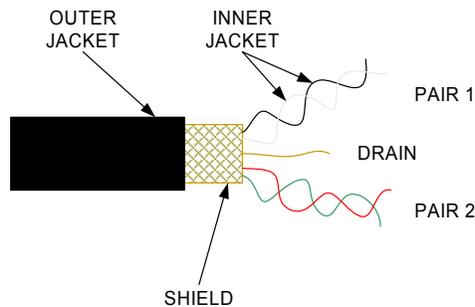


Figure 7

There are many cabling characteristics to consider when designing a system. The following list contains a few such characteristics for consideration:

- Impedance (110-120 Ohm recommended)
- Capacitance (< 25 pF cond.-to-cond., < 40 pF cond.-to-shield recommended)
- Attenuation
- Number of conductors/pairs (minimum 1 pair)
- Number of twists per foot
- Conductor material/diameter
- Wire gauge (AWG)
- Maximum current and temperature
- Inner and outer jacket material
- Minimum bend radius
- Maximum pull tension

NOTE: Many people often substitute cheaper balanced audio cable (regular microphone cable) with tragic results. Audio cable cannot support the signal rate required by the high speed DMX protocol. While the signal may pass over short distances, it is highly susceptible to interference and degradation, causing unpredictable results (such as blinking lights, confused intelligent fixtures, etc.).

4.3 Data

DMX 512 data is transmitted at 250 kiloHertz (kHz), meaning that 250,000 1's and 0's (at a maximum) can be sent each second. Each bit is measured in 4 microsecond (μs) intervals. In order for the receiving device to correctly interpret the data, it must be sent in a particular sequence. A single transmission (DMX Packet) includes synchronizing elements and channel data for up to 512 channels (Figure 8).

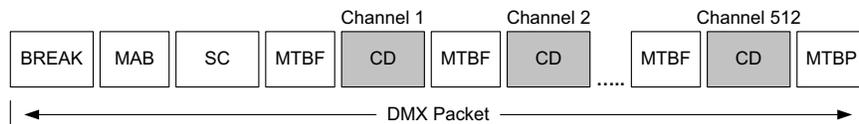


Figure 8

The following table describes each element of the DMX Packet, including its line state, size and duration. An idle DMX line will have a continuous HI (1) line state.

Table 2: DMX Packet

Element	Description	State	Size	Duration
Break	The Break resets the line, signaling a new DMX Packet.	LO (0)	22-250 kbits	88 μs - 1 sec
Mark After Break (MAB)	The MAB signals the receiver to begin reading data.	HI (1)	2-250 kbits	8 μs - 1 sec
Start Code (SC)	The SC is identical in size to channel data, but always 0 in value.	Mixed	11 bits	44 μs
Mark Time Between Frames (MTBF)	The MTBF is used to space out individual data bytes.	HI (1)	0-250 kbits	Up to 1 sec
Channel Data (CD)	The CD carries the 8-bit DMX Value for each channel, plus one start and two stop bits.	Mixed	11 bits	44 μs
Mark Time Between Packets (MTBP)	The MTBP is used to space out entire DMX Packets.	HI (1)	0-250 kbits	Up to 1 sec

NOTE: At a minimum, a fully loaded DMX Packet (data for all 512 channels) will be around 5700 bits in size. This means about 44 DMX Packets can be sent each second.

WARNING: DMX 512 has no error prevention, and is prohibited from use in life-safety applications such as pyrotechnics or set/rigging motion control.

5. Sample Applications

The figures on the following pages illustrate several different applications using various DMX products. Samples include:

- Dimmer Control
- Intelligent Fixture Control
- Dimmer & Intelligent Fixture Control
- Distributed Control

As mentioned earlier, dimmers normally use one DMX Channel per light. They translate DMX Values in a linear fashion, with 0 being off and 255 full on.

Intelligent fixtures use one DMX Channel per parameter (such as pan, tilt, color, gobo, etc.). How does the controller know which channel controls each parameter? Each intelligent fixture has a DMX Channel Mapping that matches control channels and parameters.

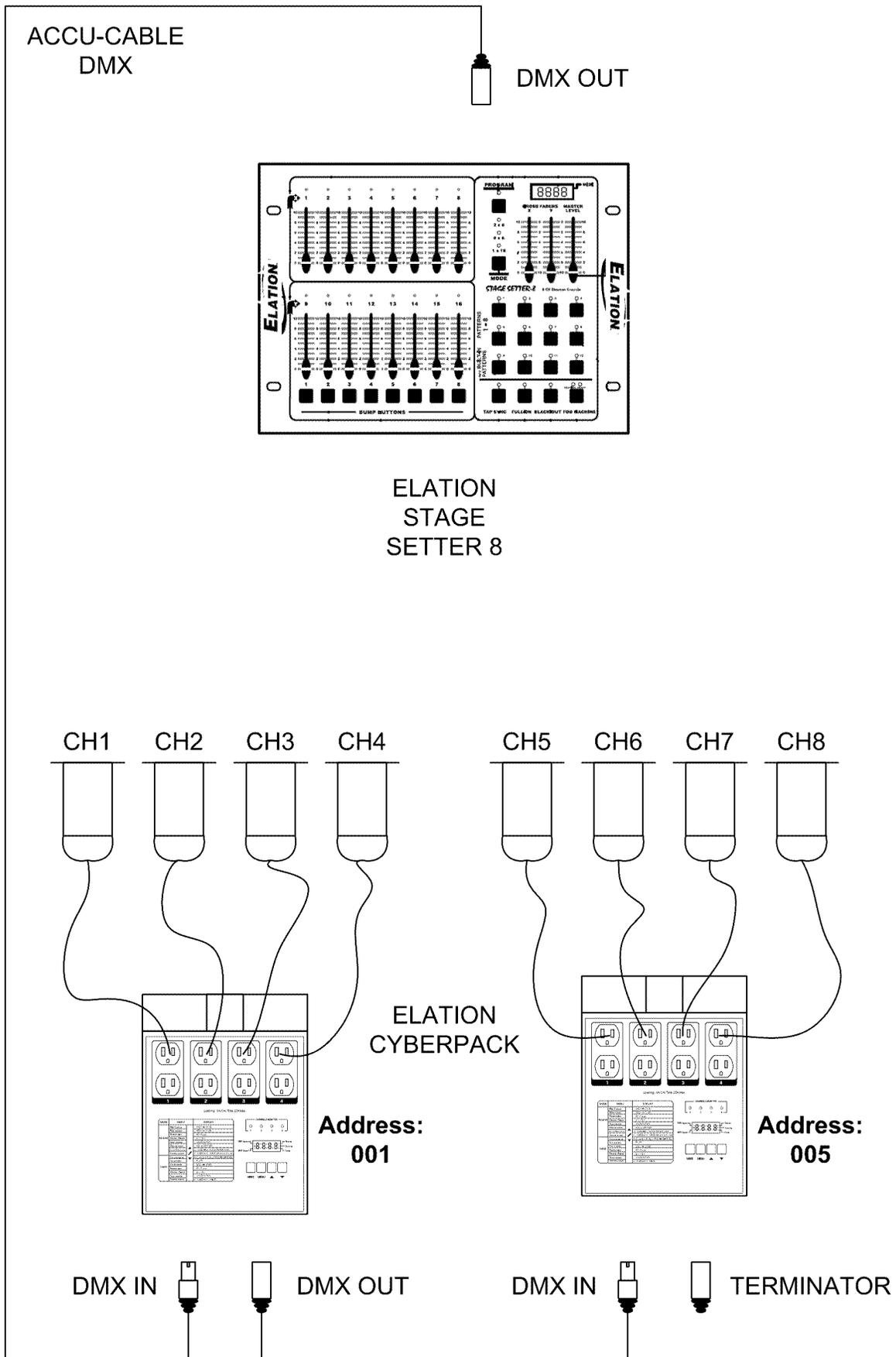
- Channel 1: Pan
- Channel 2: Tilt
- Channel 3: Color
- Channel 4: Gobo
- Channel 5: Dimmer

Pan and tilt functions are linear, but color and gobo functions present a challenge. Imagine a wheel with six colors plus open (no color). How does the controller tell the fixture which color to use? The fixture assigns a DMX Value Mapping to each color.

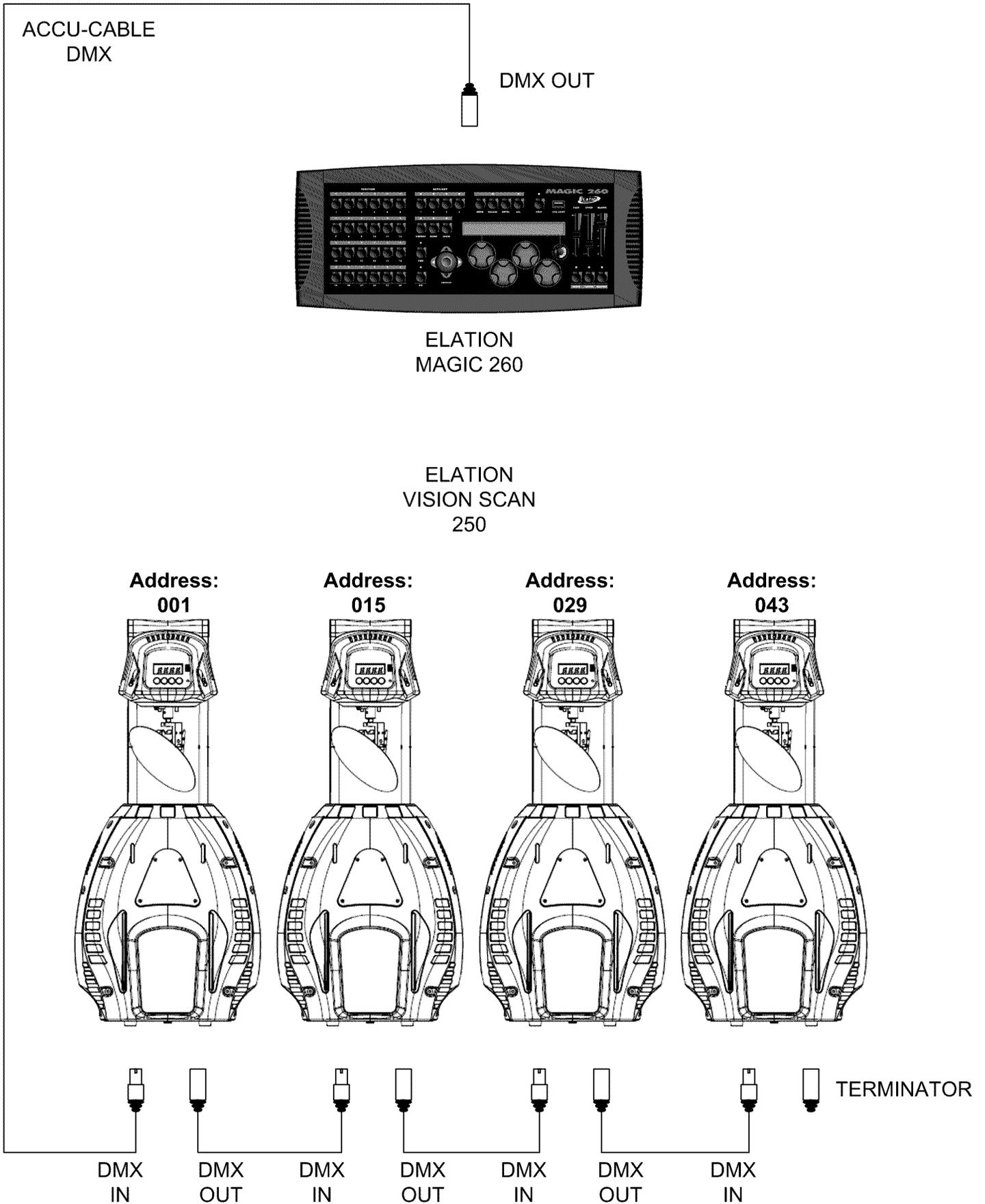
- 0-35: Open
- 36-70: Red
- 71-105: Cyan
- 106-140: Green
- 141-175: Yellow
- 176-210: Blue
- 211-255: Magenta

The DMX Channel and Value Mappings are typically saved into a computer file for each DMX controller. This file is called a Fixture Profile. In order to use a particular fixture with a controller, a current profile must be loaded. Most controllers (such as Elation's CompuLive software) come pre-loaded with thousands of fixture profiles from many different manufacturers.

5.1 Dimmer Control

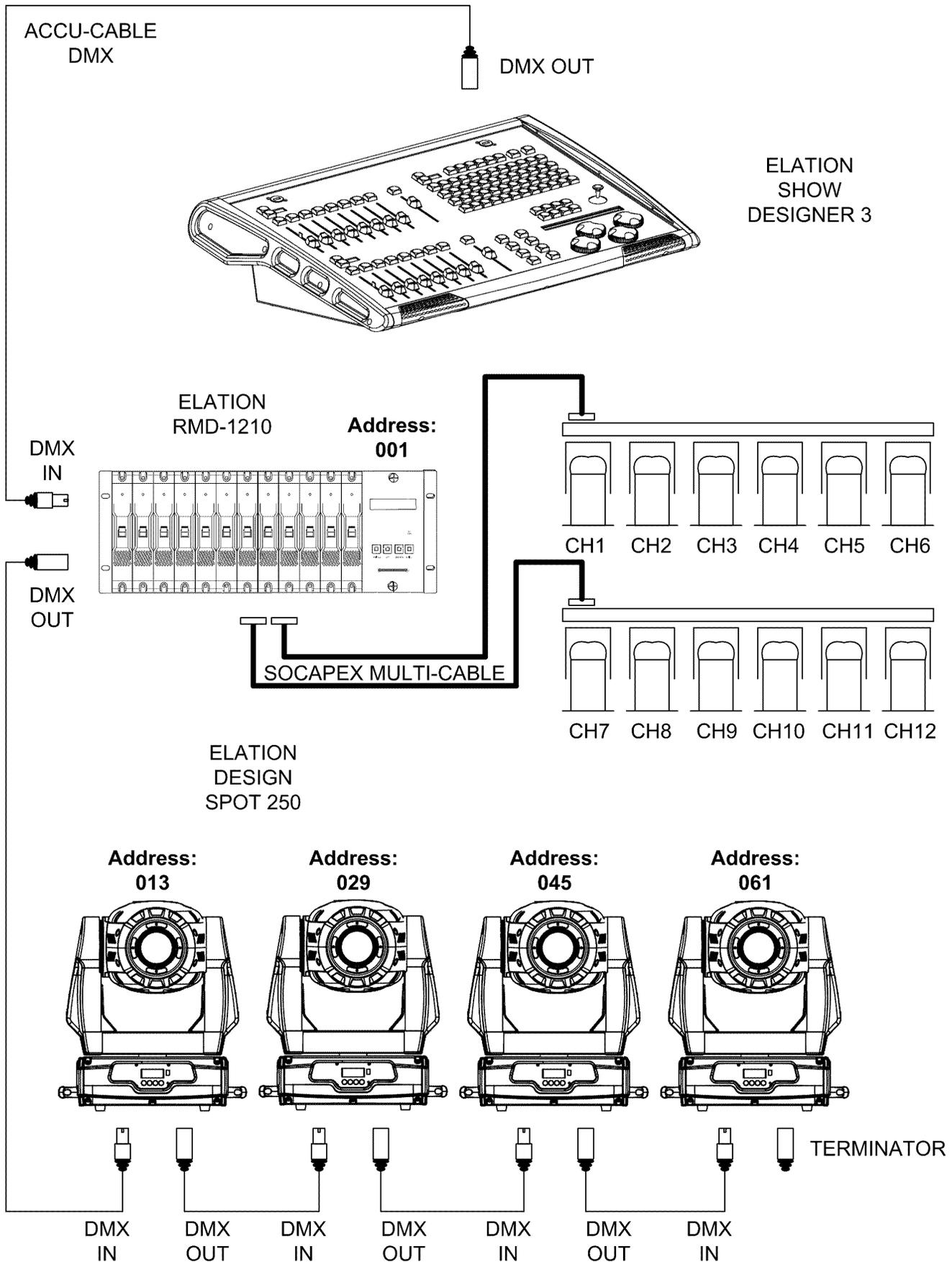


5.2 Intelligent Fixture Control

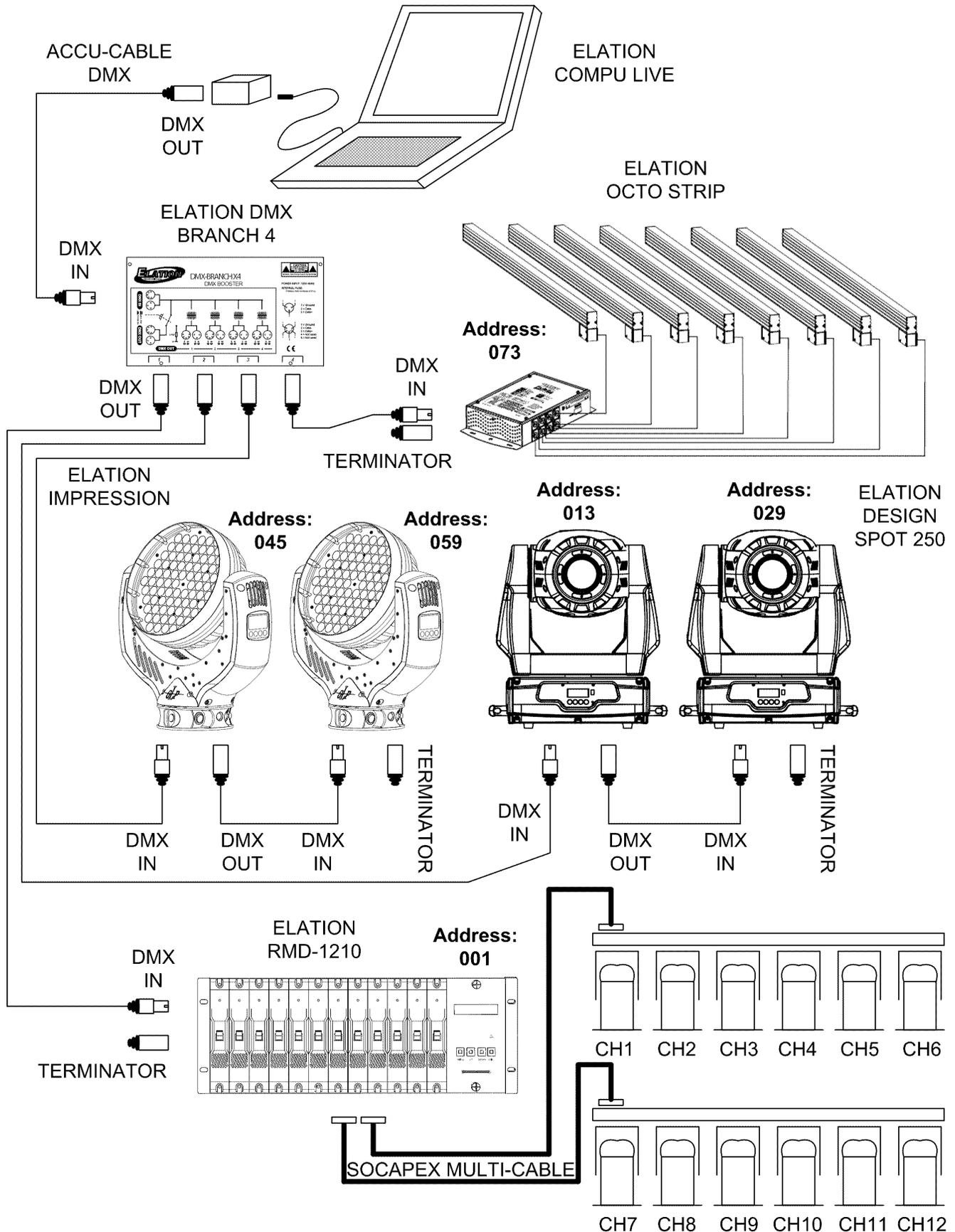


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5.3 Dimmer & Intelligent Fixture Control



5.4 Distributed Control



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