Design Note:

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Using the MAX3656 Laser Driver to Transmit Serial Digital Video with Pathological Patterns

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1 Introduction

This design note describes why the SMPTE serial digital interface (SDI) form of digital video is difficult to transmit over fiber optic links, and how the MAX3656 laser driver can be used to successfully overcome this problem.

Early digital fiber-optic transmission systems were designed to deliver digitized audio (voice) over large telecommunication networks. For example, Synchronous Optical Network (SONET) is an optical transmission standard that uses scrambling to make clock and data recovery easier. Scrambling can help randomize the data to make it easier for the receiver to recover the clock without increasing overhead data.

Uncompressed digital video also uses scrambling to help randomize the data being transmitted. However, the problem with digital video is that it can be created artificially by color generators, and digital color generators can create video with no noise. In particular, two colors do not always get adequately randomized by the scrambler and can result in repeating patterns that have either a large DC offset or a low transition density. These difficult-to-transmit patterns are called "pathological patterns." The pathological pattern containing the large DC offset is very troublesome for fiber optic transmitters. Overcoming problems with pathological patterns is the focus of this application note.

2 Pathological Pattern

The most stressful pathological pattern for a fiber optic transmitter is a repeating pattern of one high bit followed by nineteen low bits (or the inverse of this). This pattern and the inverse of this pattern are created by a specific shade of magenta. This pattern presents a mark density of 5% to the transmitter (or 95% for the inverse pattern). This is very far from the 50% mark density needed for proper performance. The pattern repeats for 26µs for HDTV signals or 53µs for SDTV signals. This is the time it takes to scan across one horizontal line of active video. To make matters worse it is possible for the pattern to repeat across successive lines of video broken only by the horizontal line blanking.

Because of how the scrambling algorithm is prescribed, video formatted in accordance with the ANSI/SMPTE 259M, 292M, 294M, and 344M standards, is subject to pathological patterns. This includes two common data rates, 270Mbps for SDTV and 1.485Gbps for HDTV.

3 Problems with Mark Densities Differing from 50%

The term "mark density" refers to the ratio of ones to zeros in a data pattern. Fiber optic systems cannot tolerate data patterns that differ far from 50% for an extended period of time. There are numerous elements in fiber optic systems that cause problems when data has long runs of non-50% mark density, but for this application note the focus will be on the transmitter.

The standard laser driver circuitry includes an automatic power control (APC) loop (details of the APC loop will follow) and possibly AC coupling on the data inputs and the laser modulator output. Both AC coupling and the APC loop react poorly to a large mark density imbalance in the signal.

AC coupling acts as a high-pass filter for the data that passes through the laser driver. If the mark density strays far from 50% for long enough, the low-frequency content of the data will fall below the cutoff frequency of this filter, causing pulse width distortion (PWD). This is because the capacitor will begin to charge in response to either a long string of consecutive identical digits (CID) or to a long term deviation from 50% mark density. After charging, the minority bits will be wider than they should be resulting in PWD. This is one type of deterministic jitter.

The APC loop acts as a low-pass filter to the laser's average power. It will respond to the deviant mark-density if it occurs long enough to fall within the loop's bandwidth. For example, if the previously mentioned pathological pattern of one high bit followed by nineteen low bits occurs long enough, the standard APC loop reacts to the pattern by adjusting the bias current. It senses that the average power seems to be decreasing and attempts to correct this by boosting the laser's bias current.

Even worse is the complementary pattern of nineteen high bits followed one low bit. In this case, the APC loop decreases the laser's bias current to maintain the average power. This time the occasional low bit passes below the laser's threshold current and causes the laser to exhibit relaxation oscillations as well as turn-on delay. These effects are described in detail in the application note: [HFAN-02.0: Interfacing Maxim Laser Drivers With Laser Diodes]

4 How Fibre Channel and Gigabit Ethernet Contend with the Mark Density Issue

SONET was designed to deal with a noisy analog audio signal that will not produce a perfectly repeating signal. This is not the case with digital data. Fibre Channel and Gigabit Ethernet were designed to deal with digitally generated data that can have a very low transition density or a large DC offset. These transmission standards use 8b/10b coding to groom the data for easy optical transmission. This encoding method guarantees at worst a 40% or 60% mark density for each 10bit word. For large numbers of sequential bits, the mark density will be close to 50%. The tradeoff is the extra bandwidth required: 8b/10b encoding increases the bit rate by 25%.

5 APC Loop Description

Traditional Maxim laser drivers such as the MAX3273, MAX3735, MAX3850, MAX3863, and the MAX3869 include an APC loop that is used to control the average power of the laser's output as the laser's characteristics change due to temperature variation and aging. The APC loop is composed of three things: the laser diode, a photodiode optically coupled to the laser diode (monitor diode), and the APC circuitry. To set the laser's average power, the user adjusts the resistance on the APCSET pin. This creates an internal current that the IC compares to the current at the monitor diode. The monitor diode's current is proportional to the laser's optical power and is used by the APC circuitry to determine the laser's average power. If the monitor diode current is less than what is set by the APCSET pin, the APC circuitry increases the laser bias current in order to boost the laser's average output power. The increased laser power boosts the amount of light falling on the monitor diode and increases the current of the monitor diode. The APC loop equilibrium condition occurs when the monitor diode current matches the desired current set by the resistance at APCSET.

6 The MAX3656's APC Loop

The MAX3656 is a burst-mode laser driver. The APC loop differs from all other Maxim laser drivers because it is implemented digitally. The MAX3656 uses a proprietary digital APC loop architecture to control the laser's average power. It was designed to deal with data containing large deviations in mark density and allows the MAX3656 to pass signals containing the pathological pattern without degrading the signal.

Figure 1 shows the MAX3656 application circuit used in this application note. The burst-enable pins (BEN±) were forced to a static differential high, setting the part into continuous-mode operation. For more information, refer to the MAX3656 data sheet.

7 Generating a Pathological Test Pattern

SMPTE specifies the pathological test patterns in SMPTE RP 198-1998 for high definition SDI, and in SMPTE RP 178-1996 for standard definition SDI. The patterns described are prior to scrambling. Since no scrambling devices were available for use in development of this design note, a specific data pattern was generated to provide an equivalent level of stress to the transmitter.

The pathological test pattern was designed to test the transient response of the laser driver going into and out-of the pathological region. This pattern consists of one video line of nineteen high bits and one low bit repeating, one line of a pseudo random code, one line of one high bit and nineteen low bits repeating, and another line of pseudo random code. (See Figure 2).

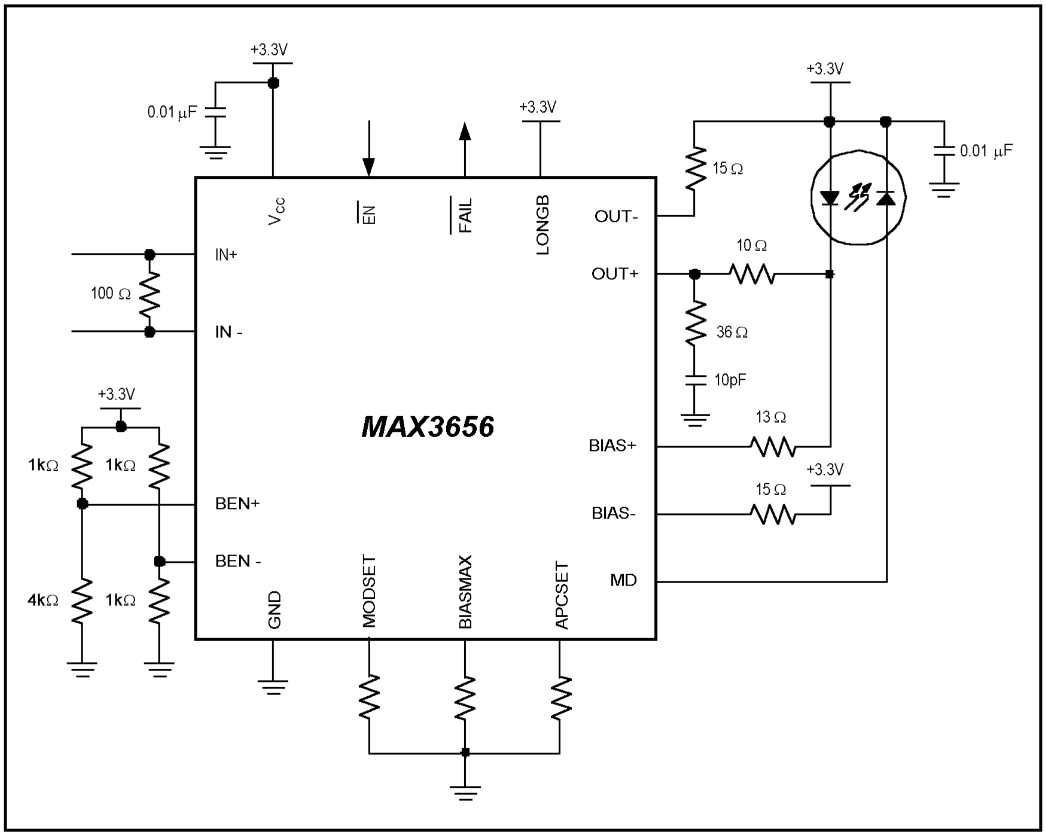

Figure 1. Application Circuit for the MAX3656

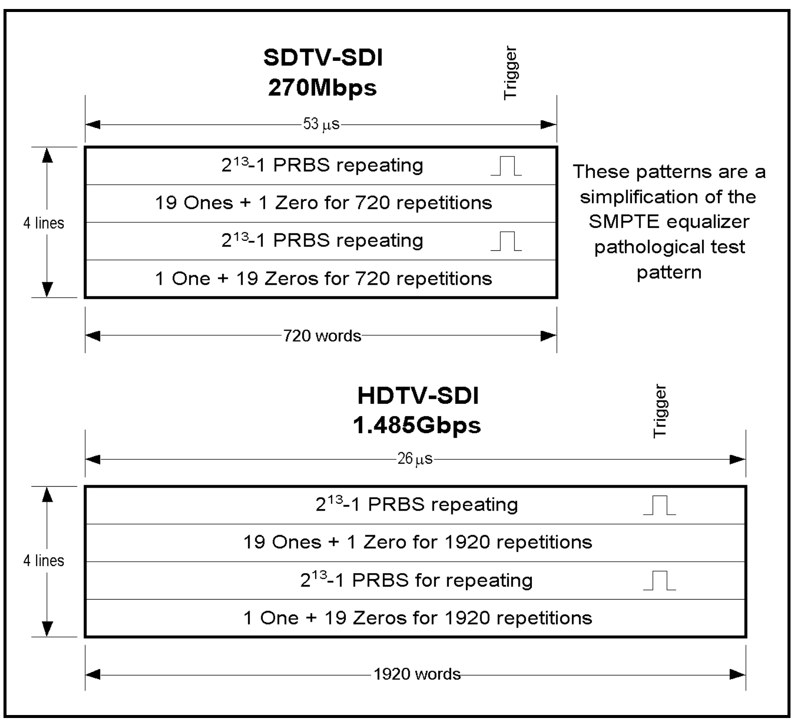

Figure 2. Test Pattern

8 Optical Eyes of a Standard Laser Driver Configuration

Figures 3 through 6 show a laser driver with a standard APC loop operating at the HDTV rate of 1.485Gbps. The APC loop's cutoff frequency is low enough to deal with the very broad spectrum of a 2^{31}-1 PRBS with very little negative response. Any negative response would show up as jitter and as "noise" on the high and low levels.

In Figure 4 the laser's output levels are good going into the pathological region. Once the pathological pattern has repeated for a substantial period, the high mark density pattern (95%) causes the APC loop to reduce the bias current so that the high level drops and the low level is forced below threshold (see Figure 5). For the low mark density pattern (5%), the high and low levels get pushed up due to the increased bias current intended to hold the average power at a constant rate.

When the pathological pattern is over and the PRBS region is entered, the signal has wandered up for the 5% mark density pattern and wandered down for the 95% mark density pattern, as seen in Figure 6. This is called "baseline wander" and leaves very little eye opening for proper data acquisition.

Notice that at the middle of the pathological region, after about 13µs, the APC loop has already completely wandered to the maximum extent, also seen in Figure 6. The time constant of the APC loop would need to be greatly extended to deal with just one line of pathological pattern at 1.485Gbps.

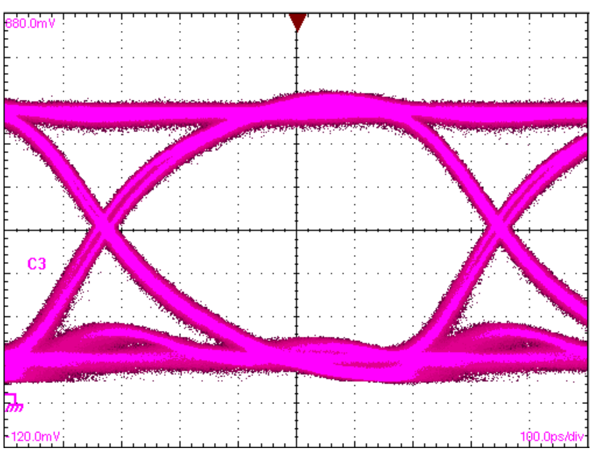

Figure 3. DC-coupled laser driver output with 2^{31}-1 PRBS operating at 1.485Gbps (standard APC loop).

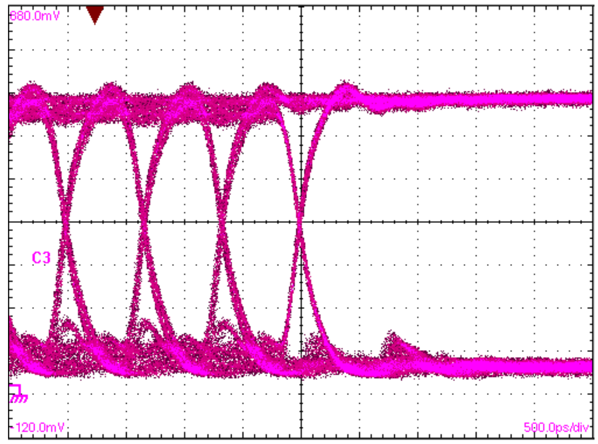

Figure 4. DC-coupled laser driver output with the HDTV-SDI test pattern, entering the pathological region (standard APC loop).

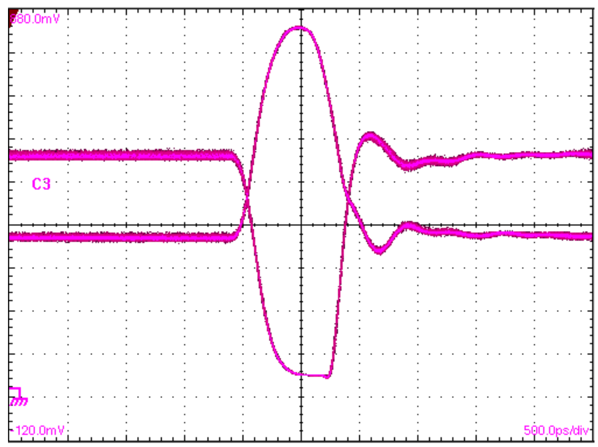

Figure 5. DC-coupled laser driver output with the HDTV-SDI test pattern, middle of pathological region (standard APC loop).

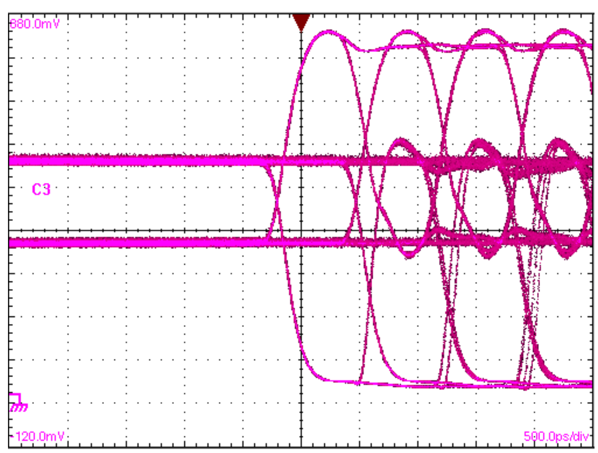

Figure 6. DC-coupled laser driver output with the HDTV-SDI test pattern, exiting pathological region (standard APC loop).

9 Optical Eyes of the MAX3656

Figures 7 through 14 show the MAX3656 operating in continuous mode (not burst-mode) with a pseudo random pattern, and with the test patterns shown in Figure 2.

Relative to the standard laser driver, this laser driver's APC loop is digital and does not respond to a non-fifty percent mark density by boosting or decreasing the bias current and creating baseline wander. Instead, it holds steady due to the digital APC circuit's ability to ignore mark density deviations.

9.1 HDTV rate of 1.485Gbps

Similar to the standard laser driver, the MAX3656 enters the pathological region with good levels for both the high and low bits (Figure 8). Unlike the standard laser driver, the MAX3656 maintains good levels at the middle and at the end of the pathological region, as seen in Figures 9 and 10.

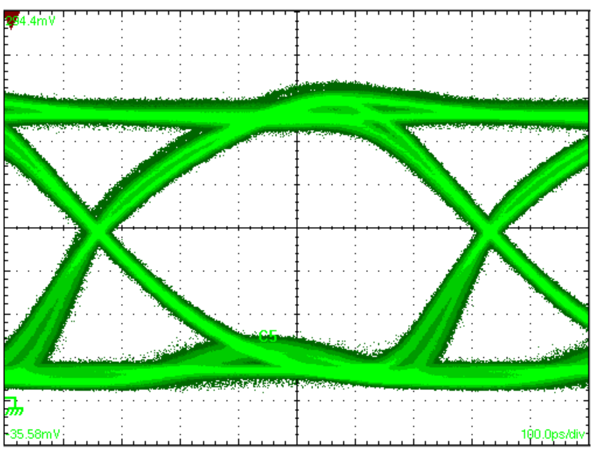

Figure 7. MAX3656 optical eye with a 2^{31}-1 PRBS operating at 1.485Gbps.

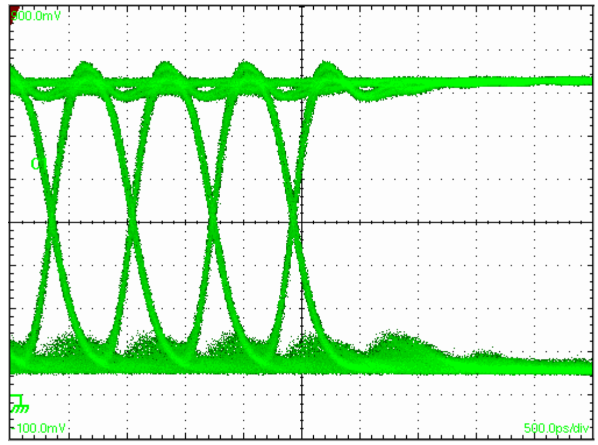

Figure 8. MAX3656 optical eye with the HDTV-SDI test pattern beginning of pathological region.

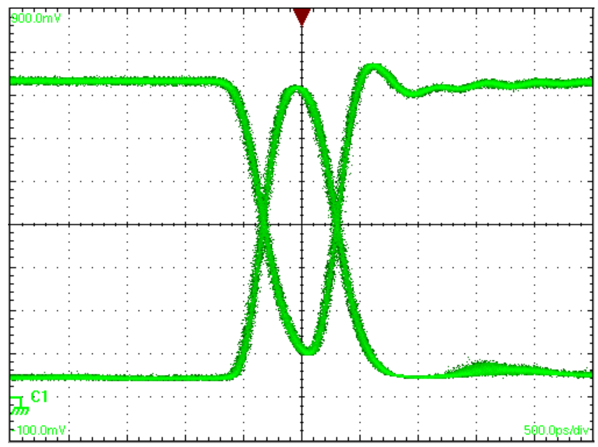

Figure 9. MAX3656 optical eye with the HDTV-SDI test pattern, middle of pathological region.

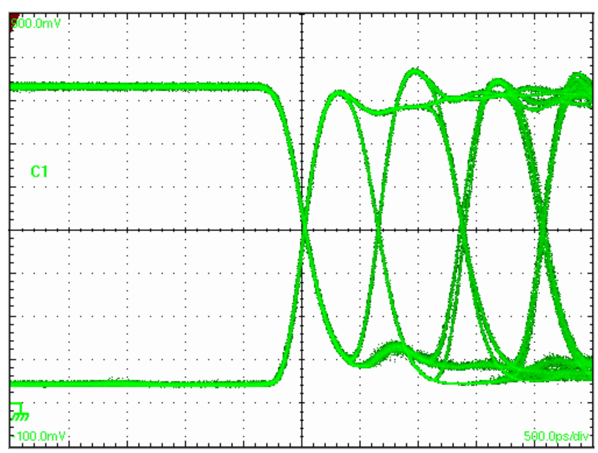

Figure 10. MAX3656 optical eye with the HDTV-SDI test pattern, end of pathological region.

9.2 SDTV rate of 270Mbps

The following figures show the MAX3656 operating with the SDTV-SDI test pattern shown in Figure 2. Similar to its performance at 1.485Gbps, it performs very capably at the SDTV rate of 270Mbps.

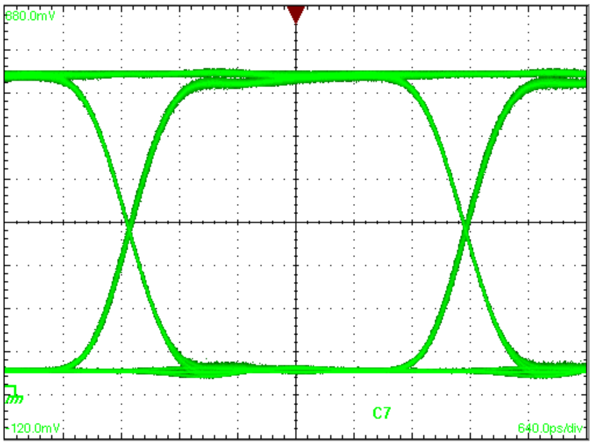

Figure 11. MAX3656 optical eye with 2^{31}-1 PRBS at 270Mbps.

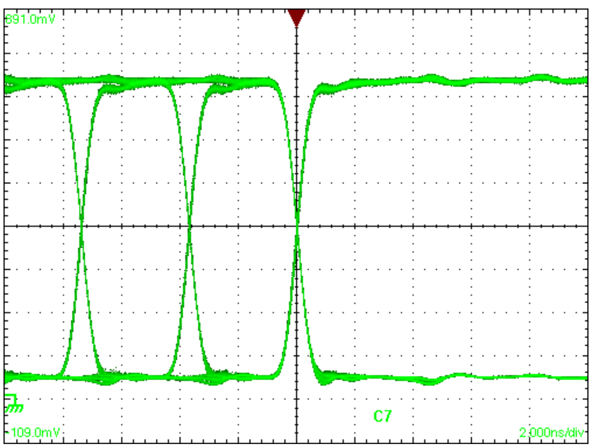

Figure 12. MAX3656 optical eye with the SDTV-SDI test pattern, beginning of pathological region.

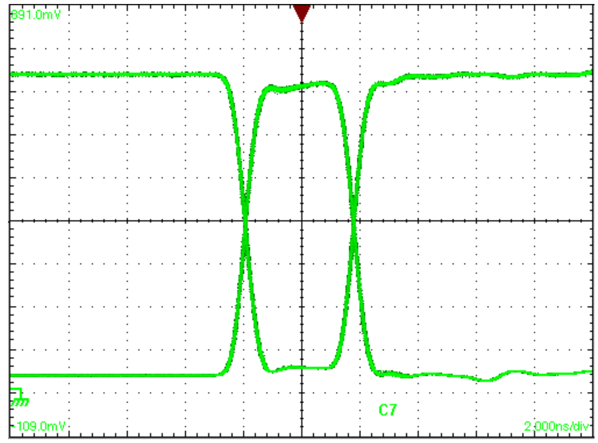

Figure 13. MAX3656 optical eye with the SDTV-SDI test pattern, middle of pathological region.

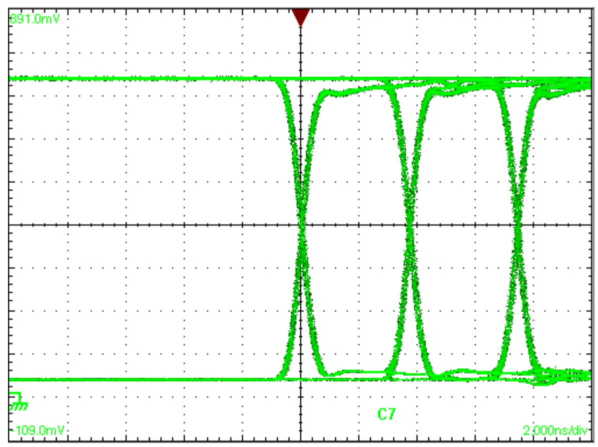

Figure 14. MAX3656 optical eye with the SDTV-SDI test pattern, end of pathological region.

10 Summary of Results

Figures 3 through 6 show a laser driver with a standard APC loop encountering various patterns. Even though this laser driver was DC coupled at the inputs and to the laser, the eye still suffered significantly when subjected to a pathological sequence. The APC loop does not have a long enough time constant to deal with the long periods of 5% or 95% mark density. Note that the APC loop's time constant is set with a capacitor and the recommended value for scrambled data was used.

Figures 7 through 14 show the MAX3656 in the same circumstances as the standard laser driver. The improvement is quite evident at the middle and end of the pathological pattern. Because of this laser driver's burst-mode design focus, we gain a side benefit of greatly improved baseline wander rejection which helps immensely when transmitting video with pathological patterns.

References:

Society of Motion Picture and Television Engineers 1997. SMPTE Standard for Television – 10-Bit 4:2:2 Component and 4f_{SC} Composite Digital Signals – Serial Digital Interface. SMPTE 259M-1997

Society of Motion Picture and Television Engineers 1998. SMPTE Standard for Television – Bit-Serial Digital Interface for High-Definition Television Systems. SMPTE 292M-1998

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