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Vector Modulation Analysis Software MX280005A Vector Signal Analyzer Applications

For use with Anritsu Spectrum Analyzers Supporting Option 128

Introduction

The Vector Signal Analyzer (VSA) is a PC-based software program which performs measurements on digitally modulated signals. An Anritsu hardware receiver/analyzer is first used to convert the RF signal into its complex baseband components. These components are referred to as I/Q signals where 'I' is the in-phase (phase reference) and 'Q' is the quadrature signal (90° out of phase). The captured I/Q files are then transmitted to the PC for various measurements relating to signal quality.

This application note provides a high level overview of the demodulation process as well as insights that can be made from the analysis process. Anritsu's VSA can be used both for design validation as well as for the investigation of problems such as component degradation, RF channel impairments, and interference.

I/Q Conversion Process

Information is encoded into the RF signal by modulating the RF carrier. Once received, each signal is digitized into a bit pattern which in turn is decoded by the receiver. Figure 1 shows an example of a quadrature phase shift key (QPSK) signal. Since there are four possible states in a QPSK signal, each state (or symbol) requires two bits to determine its position in the I/Q plane. Higher orders of modulation such as 8PSK or 16PSK require more bits per symbol. More information is carried with these modulations at the expense of a higher susceptibility to bit error rates.

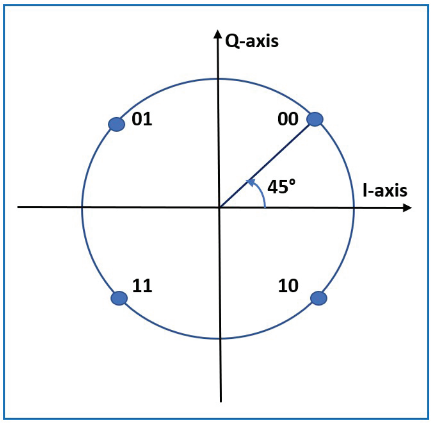


Figure 1. QPSK Constellation Diagram

The demodulation process begins after the transmitted RF signal is first down-converted to a lower, intermediate frequency (IF), filtered, and presented to an analog-to-digital converter (ADC) in the receiver. A detector then splits the signal into both its in-phase and quadrature components to subsequently be processed by the VSA. The "I" and "Q" components of the signals are in the time domain. By performing a transformation, the digital stream can be Fourier transformed (FT) or fast Fourier transform (FFT) for display in the frequency domain. This is the display typically used by spectrum analyzers (Figure 2).

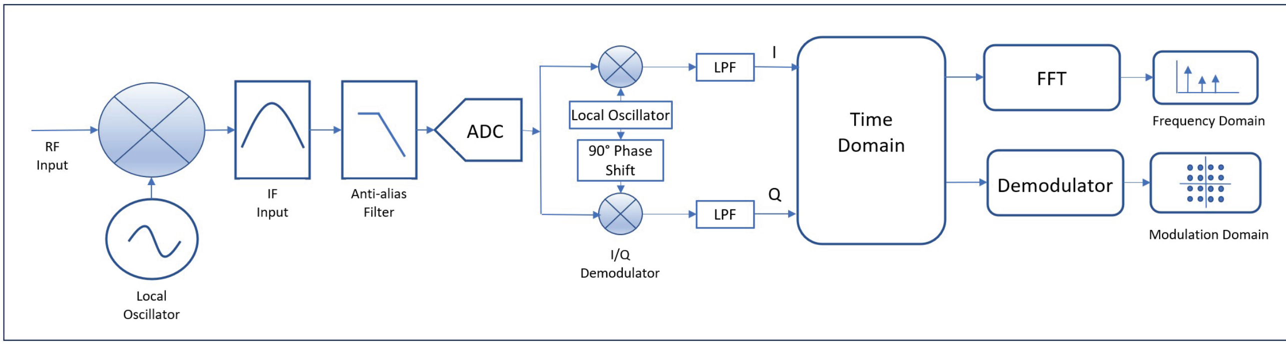


Figure 2. Receiver Topology

Once the signal is transformed into the frequency domain, phase information is lost. Although power levels as a function of frequency can be displayed, phase information is critical for signal quality estimations such as error vector magnitude (EVM) and bit error rate (BER) measurements. The demodulation is therefore conducted while the signal is still in the time domain.

Demodulation Parameters

Digital signals are modulated using at least one of the parameters listed below.

- Frequency Modulation
- Phase Modulation
- Amplitude Modulation

The various lower-level modulation types supported by the Anritsu VSA are listed in Table 1 according to the categories listed above.

Table 1. Modulation Types Supported by Anritsu Vector Signal Analyzer

Modulation Types Supported by Vector Signal Analyzer (Option 128)				
Amplitude		**Phase**		**Frequency**
16QAM	32QAM	BPSK	QPSK	2FSK
64QAM	128QAM	O-QPSK	π/4 DQPSK	4FSK
256QAM	512QAM	8PSK		H-CPM
1024QAM	2048QAM			MSK
16APSK	32APSK			

Given the finite spectrum available, the user is interested in transmitting as much information as possible in a given frequency bandwidth. A figure of merit for spectrum efficiency is bits/s/Hz, for example, useful information transmitted in bits/second in a 1 Hz of bandwidth. Calculations for spectral efficiency for various modulation types are listed. Efficiency numbers are calculated as information thruput only. Table 2 shows the theoretical maximum thruput for each modulation type. Actual information transmission depends on signal overhead such as error correction coding, training bits, and upper layer signaling.

Table 2. Spectral Efficiencies for Various Modulation Types

Spectral Efficiency for Various Modulation Methods	
Type of Modulation	**Spectral Efficiency (bits/s/Hz)**
GMSK	1.35
BPSK	1
QPSK	2
8PSK	3
16QAM	4
64QAM	6
OFDM	>10 (depends on modulation type and subcarrier number

Modulation Analysis

The VSA performs multiple measurements on the I/Q signal. Highlights of a few commonly used signal analysis formats will be shown.

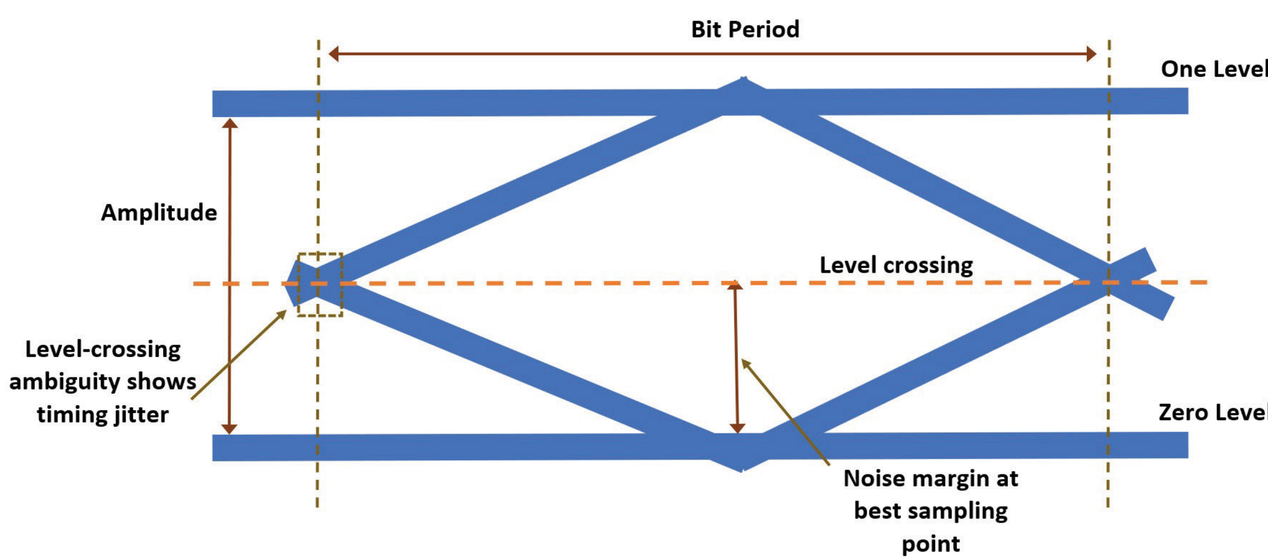


Figure 3. Eye Diagram

Various parameters display by the Eye Diagram include:

- **One Level –** This is the mean value of a logic one. The actual value computed comes from the mean of all data samples captured in the middle 20% of the eye period.
- **Zero Level –** This is the mean value of a logic zero. The measurement comes from the mean of all samples captured in the same middle 20% of the eye period.
- **Amplitude –** This is the difference between the one and zero. Any measurement above the level crossing is received as a “1” and below the crossing as a logic “0”.
- **Eye Height –** This indicates the relative signal-to-noise ratio (SNR) in the receive system. An ideal eye opening would be equivalent to the amplitude measurement. Traces seen between the “0” and “1” level are indicative of noise in the received signal.
- **Bit Period –** This is a measurement of the horizontal opening of the eye diagram at the crossing points. The data rate of the signal can be computed as the inverse of the bit period. The period is generally called the unit interval (UI) and is shown as an absolute time measurement on the X-axis. This allows a ready comparison between signals having different data rates.
- **Timing Jitter –** Jitter is shown by the level crossing. Minimal jitter is presented at the 50% amplitude level. Jitter results from the misalignment of rise and fall times.

The Trellis diagram (figure 4) is helpful for mapping the phase trajectory of the signal vs time. After a defined number of symbols, the plot is wrapped around to the plot origin. These diagrams are typically used where signals have constant amplitude and impart information by phase transitions. In the Anritsu VSA, the phase transition for each 1/8th of the symbol in the analysis interval is displayed in degrees. The horizontal axis shows intervals of two symbols. The Trellis diagram is useful for troubleshooting missing transitions or errors in the mapping algorithm used.

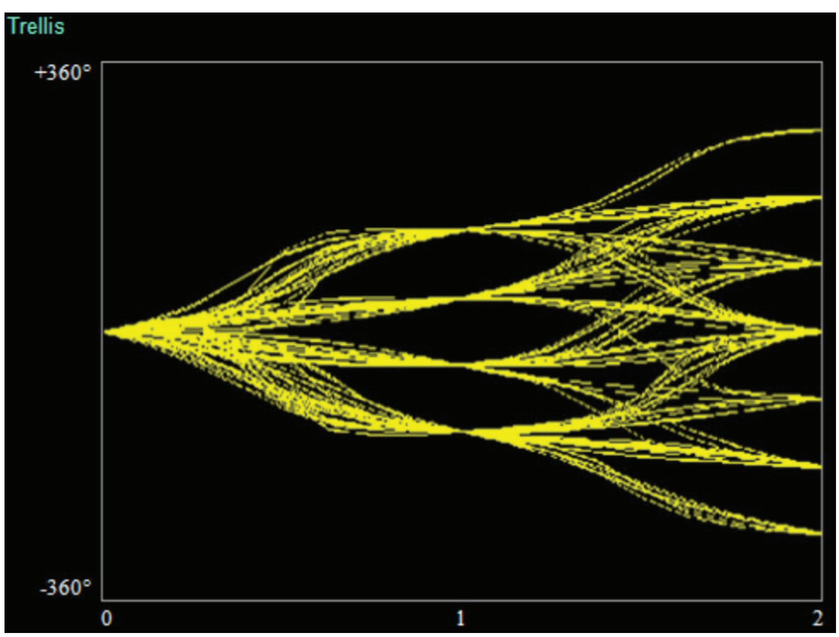
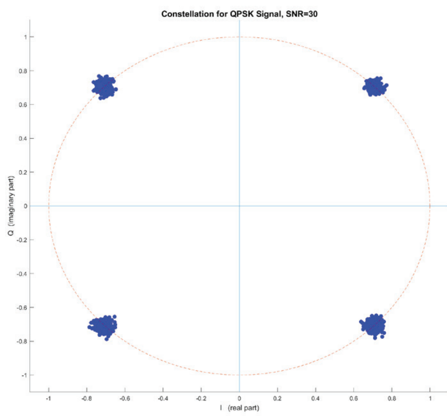


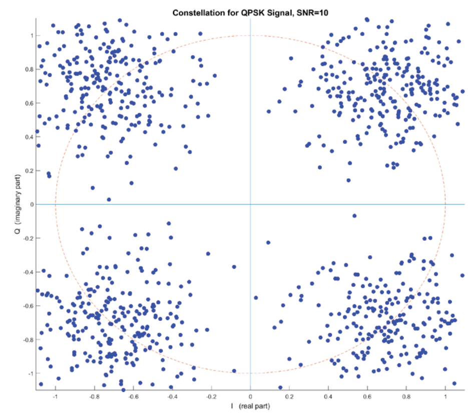
Figure 4. Trellis Diagram

Constellation Diagram

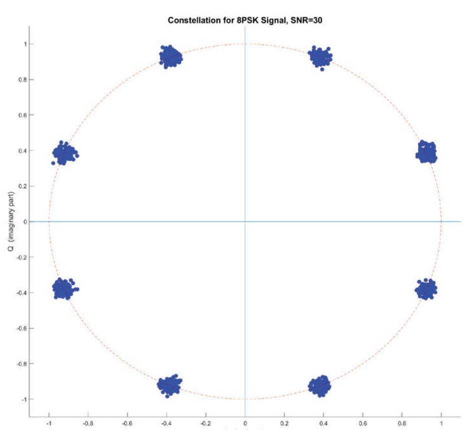
The constellation diagram is a mapping of symbols onto the I-Q plane. Information is graphically presented showing the amplitude and phase error for a given signal. A good estimation of the probability of bit (modulation) errors can readily be seen. To illustrate the process, two modulations types are shown along with varying levels of noise added to the system. It can be clearly seen that as noise is added to the signal, the probability of bit error increases, see figure 5.



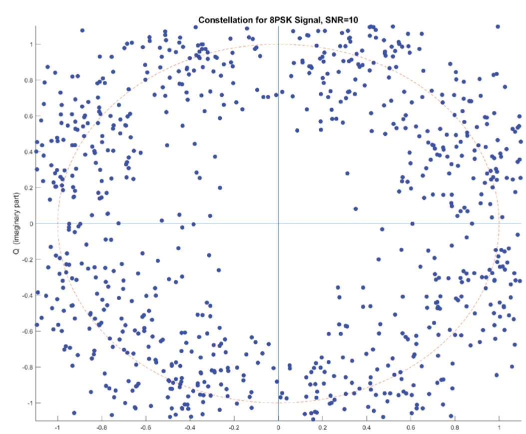
QPSK Constellation with SNR = 30 dB



QPSK Constellation with SNR = 10 dB



8PSK Constellation with SNR = 30 dB



8PSK Constellation with SNR = 10 dB

Figure 5. Constellation Diagrams Comparing Several Modulation Types at Various Noise Levels
8PSK is More Spectrally Efficient, but More Susceptible to Bit Errors When Noise is Present

These plots also show that as the modulation level increases to provide more information thruput, the probability of degraded BER increases. The QPSK plot shows that even with a SNR of 10 dB, the probability for bit errors is still relatively insignificant. However, the 8PSK plot shows that the BER increases significantly. The decision region for each QPSK symbol is mapped to each quadrant in the I-Q plane. However, for 8PSK the detection regions are pie shaped with each ‘slice’ being 22.5° wide.

Interpreting Constellation Errors

Constellation diagrams provide a useful graphical representation of EVM errors (magnitude and phase).These errors can be caused by both channel impairments as well as issues with the transmitter and receiver. Figure 6 shows a diagram describing the EVM measurement process.

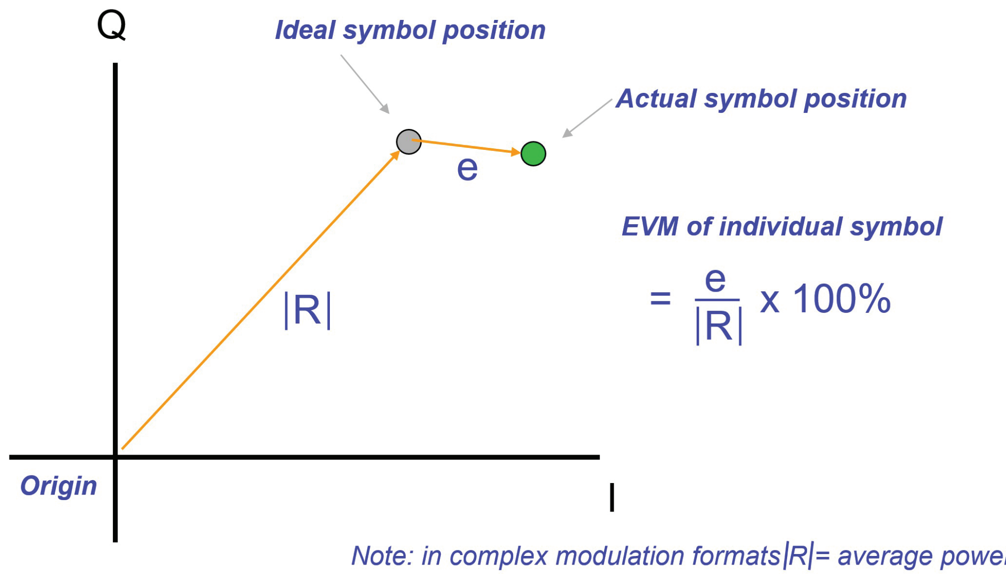


Figure 6. EVM Measurement Example

In figure 6, the ideal symbol position is shown by the grey dot. The actual symbol measured is highlighted in green. The distance 'e' represents the error.

Figure 7 highlights various errors seen in the constellation along with a suggested reason for each impairment. These diagrams can be helpful in formulating a diagnosis of the problems causing EVM errors.

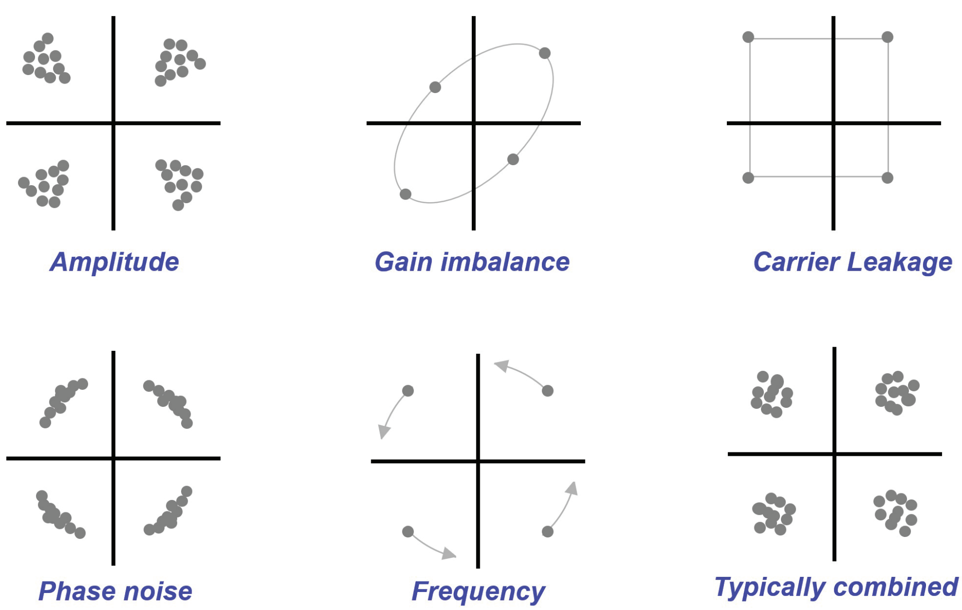


Figure 7. Constellation Diagram Analysis

Examples for modulation types used in various technology standards are shown below.

Table 3. Modulations Types Used in Various Communication Standards

Modulation Types Used in Various Communication Standards	
Technology	**Modulation**
WLAN (802.11a/g)	BPSK, QPSK, 16QAM,64QAM
Bluetooth EDR	π/4 DQPSK
DVB-S	QPSK
DVB-S2	BPSK, QPSK, 16APSK, 32APSK
DVB-DSNG	8PSK, 16QAM
TETRA	π/4 DQPSK
DMR	4FSK

Applications

Various modulation formats are used in analog and digital communications. Table 4 below shows some common applications and their associated modulation types.

Table 4. Modulation Formats Typically Used in Different Applications

Modulation Format Applications	
Modulation Format	**Application**
MSK, GMSK	GSM, CDPD
BPSK	Deep space telemetry, cable modems
QPSK, π/4 DQPSK	Satellite, CDMA, TETRA, DVB-S, cable modems
OQPSK	CDMA, Satellite
FSK, GFSK	DECT, land mobile, public safety
8PSK	Satellite, aircraft
16 QAM	Microwave digital radio, DVB-C, DVB-T
32 QAM	Terrestrial microwave, DVB-T
64 QAM	DVB-C, broadband set top boxes
256 QAM	Modems, DVB-C (Europe)

Various high-level modulation types will use the low-level formats listed above. For example, orthogonal frequency division multiplex (OFDM) is used in many versions of WLAN. The OFDM band is divided into 64 channels (subcarriers) using BPSK, QPSK, 16QAM, or 64QAM. The type of low-level format used is dependent on the RF environment to achieve maximum thruput.

In order to use a modulation type appropriate to the transmission channel, adaptive modulation is employed. As the radio signal loses power or encounters interference, the BER increases. In these situations, the modulation format is automatically shifted to a more robust modulation type that is better immune to a noisy channel. To illustrate one example of the use of low-level modulation types for high-level signals, the satellite communications standard is examined.

Satellite Communications

Ideally, a modulation type would provide maximum spectral efficiency (bits/s/Hz) while being resistant to channel distortion. Amplitude phase shift keying (APSK) is used to satisfy this requirement. An I-Q map of a 32APSK constellation is shown in figure 8. The r1/r2/r3 vectors measure distance (amplitude) between the rings. APSK transmits more bits per symbol than other phase shift systems such as QPSK while allowing more information to be transmitted. The symbol positions in the concentric rings for 32APSK are arranged in a format whereby an amplitude expansion (or compression) minimizes the probability that a bit error will occur. These problems are often seen as the RF signals are transmitted thousands of miles to/from earth orbit.

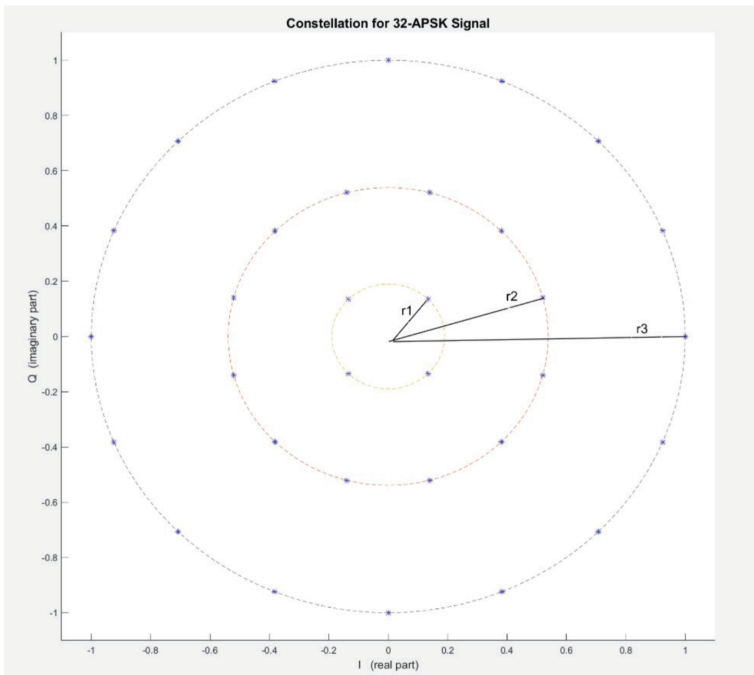


Figure 8. 32APSK Constellation Diagram

For satellite communications, the Digital Video Broadband Satellite, 2nd generation (DVB-S2) standard is used in many applications. The first generation of this standard uses BPSK and QPSK. The second generation adds 8PSK, 16APSK, and 32APSK. The standard utilizes adaptive coding and modulation (ACM) to allow optimization of bandwidth as the RF environment changes over time. It is not unusual to see different low-level modulation types for different frames in a DVB-S2 signal.

Conclusion

The Vector Signal Analysis MX280005A PC Software is used to analyze IQ data from Anritsu analyzers. This vector signal analysis software is intended for testing physical layer modulation quality of various transmission standards such as FSK, PSK, QPSK, QAM, and more. The software will only demodulate IQ data captured on an Anritsu analyzer with Option 128 installed. Multiple analysis formats are provided including signal spectrum, EVM, constellation diagrams, eye diagrams, and numeric tables. A comprehensive insight into all aspects of the transmitter performance is provided as multiple results windows can be displayed simultaneously.

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11410-02853 Rev. A Printed in United States 2021-03