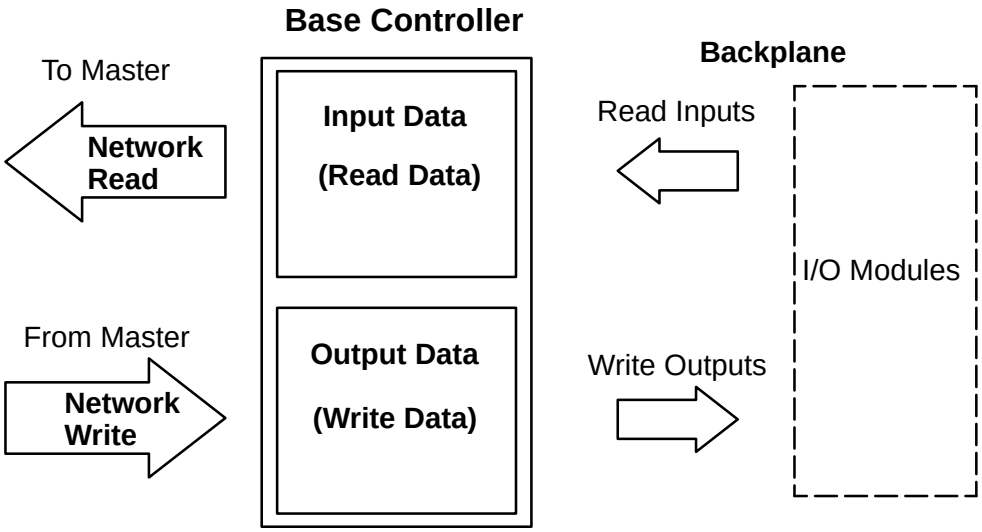
4

I/O Memory Map and Analog Module Resolution

In This Chapter. . . .

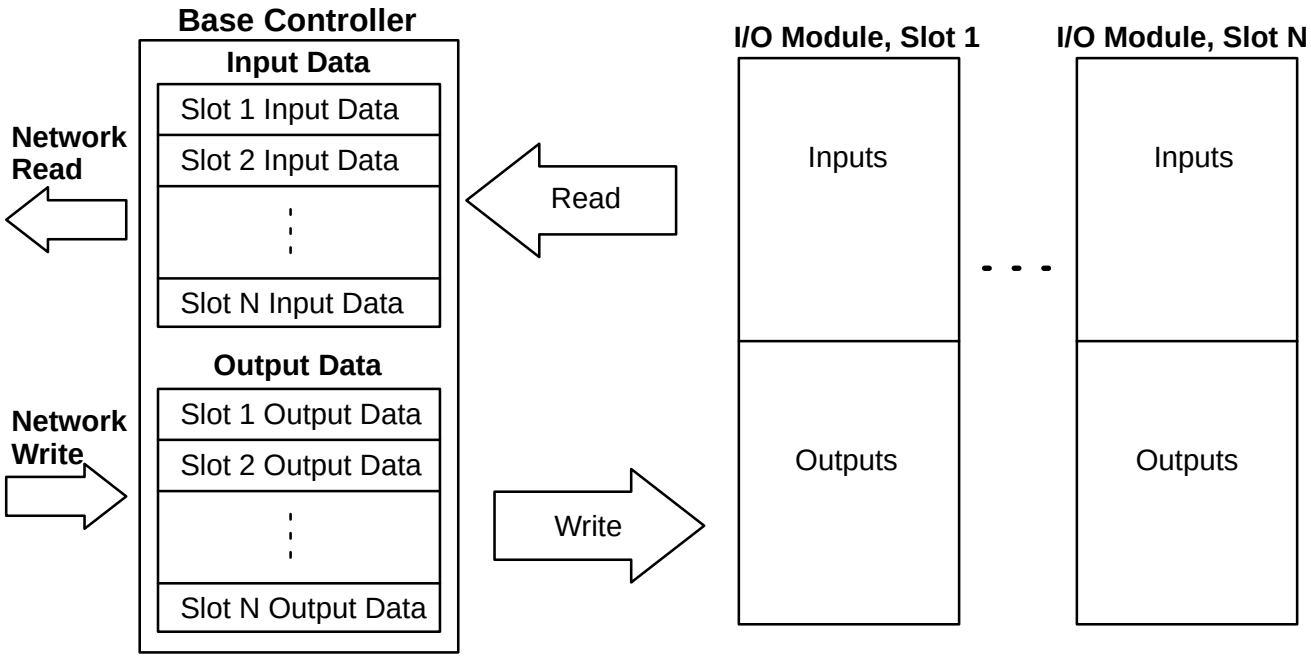
Master/Slave Communications

The base controller (slave) communicates with the master by sending Input Data and receiving Output Data. The base controller *reads* Inputs from I/O Modules and *writes* Outputs to I/O Modules.



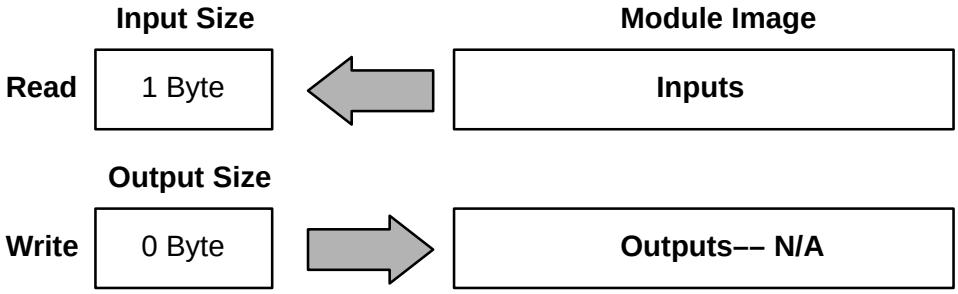
Terminator I/O Backplane Communications

The base controller communicates with its I/O modules over the backplane. The I/O is mapped in consecutive order as shown.



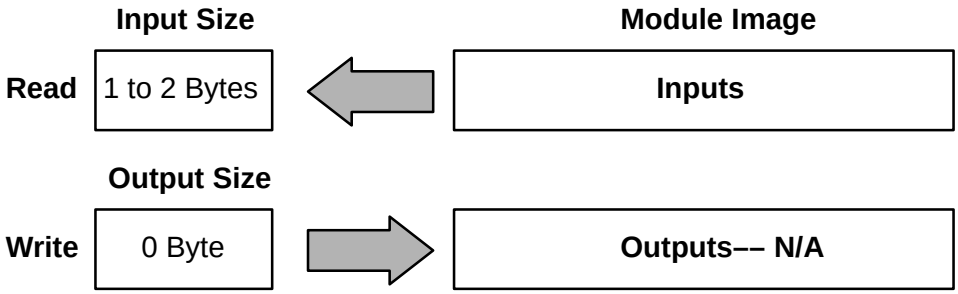
Discrete Input Module Memory Map

8-Point Discrete Input Modules (T1K–08NA–1 and T1K–08ND3) Image Table Mapping



Memory Map of 8-Point Discrete Input Modules									
Decimal Bit	07	06	05	04	03	02	01	00	Size
Octal Bit	07	06	05	04	03	02	01	00	
	X7	X6	X5	X4	X3	X2	X1	X0	Read Byte 1
Not Used									Write Byte 1

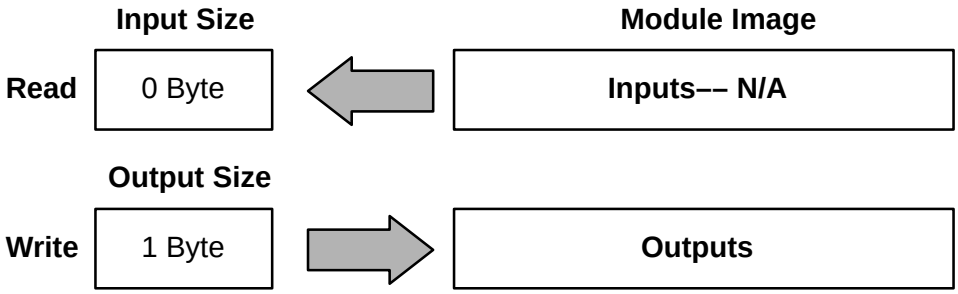
16-Point Discrete Input Modules (T1K–16NA–1 and T1K–16ND3) Image Table Mapping



Memory Map of 16-Point Discrete Input Modules									
Decimal Bit	07	06	05	04	03	02	01	00	Size
Octal Bit	07	06	05	04	03	02	01	00	
	X7	X6	X5	X4	X3	X2	X1	X0	Read Byte 1
	X17	X16	X15	X14	X13	X12	X11	X10	Read Byte 2
Not Used									Write Byte 1

Discrete Output Module Memory Map

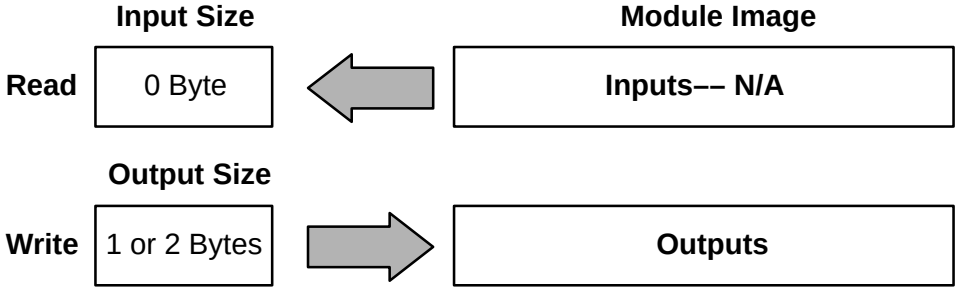
8-Point Discrete Output Modules (T1K–08TA(S), T1K–08TD1, T1K–08TD2–1 and T1K–08TR(S)) Image Table Mapping



Memory Map of 8-Point Discrete Output Modules									
Decimal Bit	07	06	05	04	03	02	01	00	Size
Octal Bit	07	06	05	04	03	02	01	00	
Not Used									Read Byte 1
	Y7	Y6	Y5	Y4	Y3	Y2	Y1	Y0	Write Byte 1

16-Point Discrete Output Modules (T1K–16TA, T1K–16TD1, T1K–16TD2–1 and T1K–16TR)

Image Table Mapping

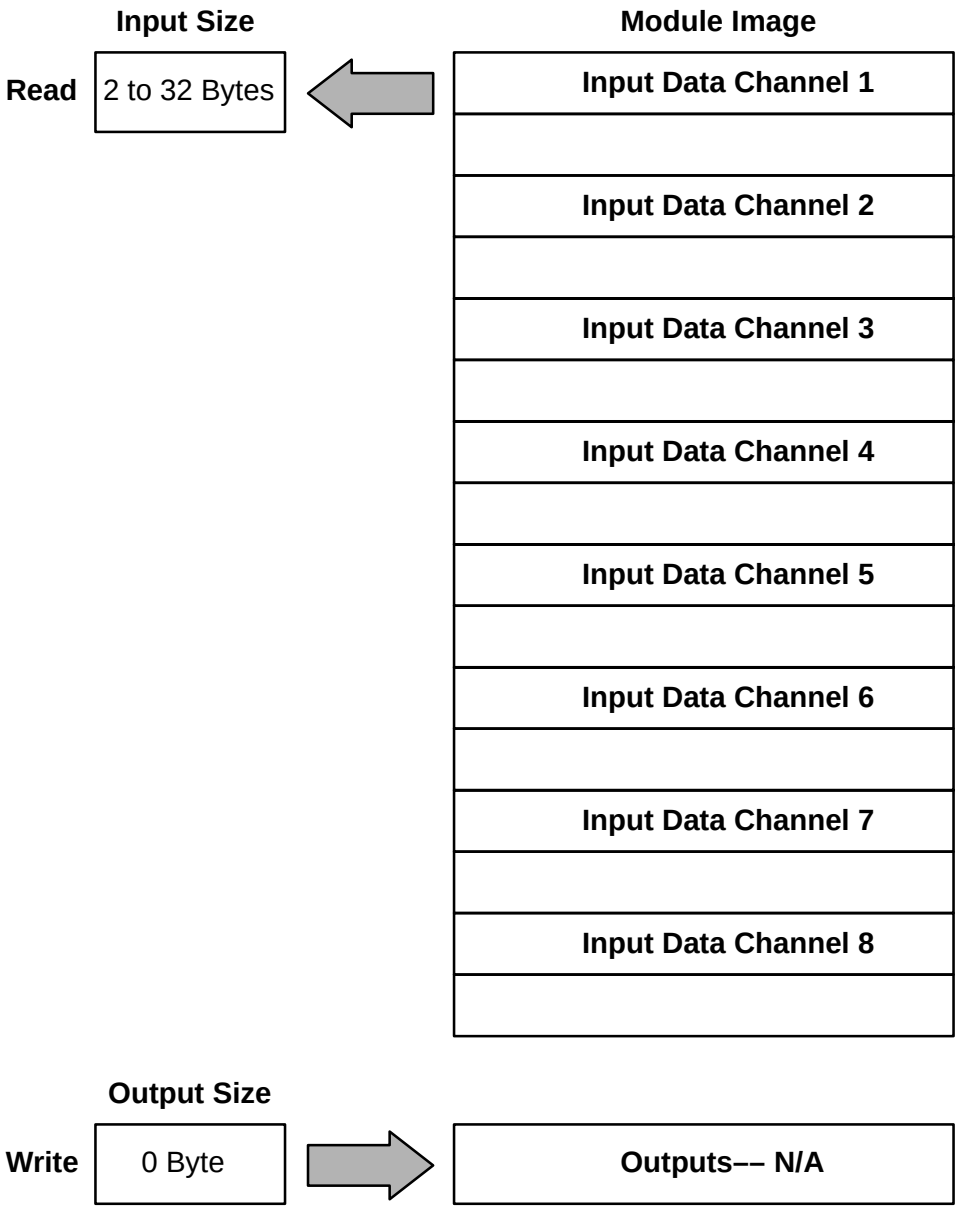


Memory Map of 16-Point Discrete Input Modules									
Decimal Bit	07	06	05	04	03	02	01	00	Size
Octal Bit	07	06	05	04	03	02	01	00	
Not Used									Read Byte 1
	Y7	Y6	Y5	Y4	Y3	Y2	Y1	Y0	Write Byte 1
	Y17	Y16	Y15	Y14	Y13	Y12	Y11	Y10	Write Byte 2

Analog Input Module Memory Map

8-Channel Analog Input Module (T1F–08AD–x)

Image Table Mapping

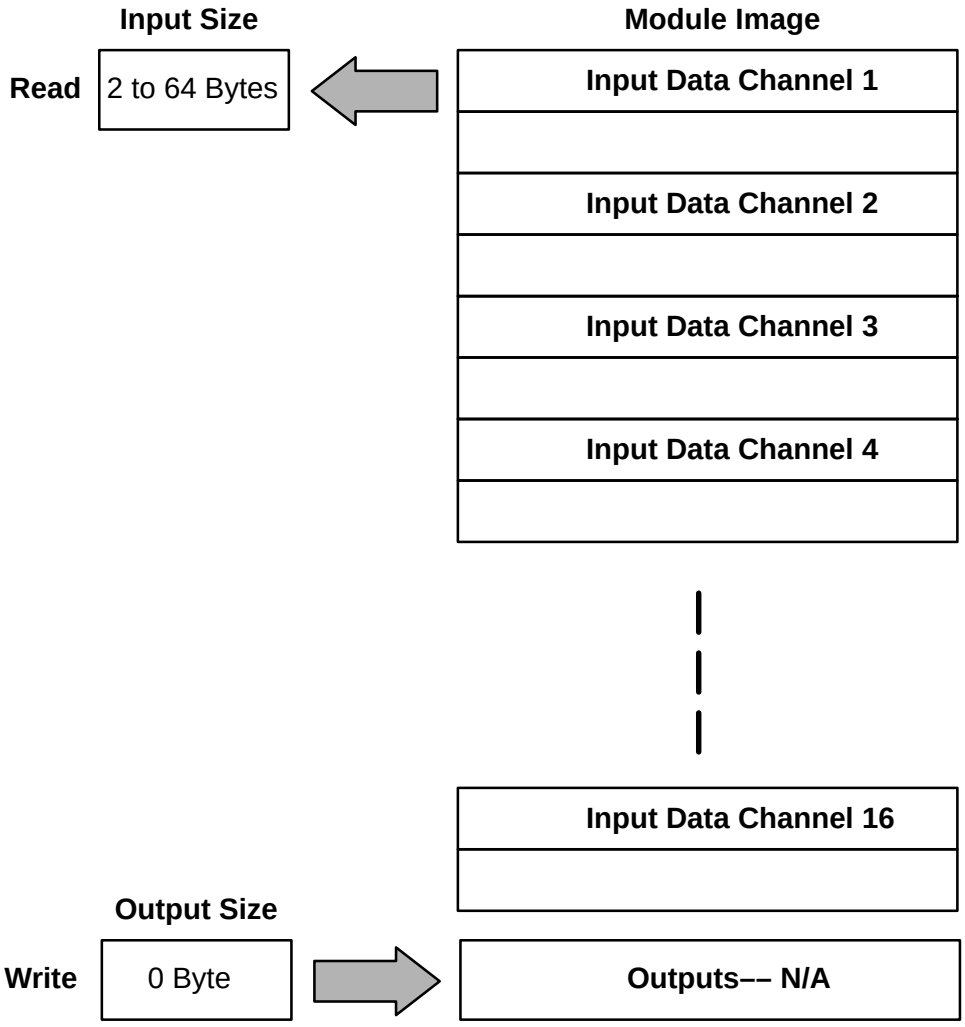


Memory Map of 8-Channel Analog Input Module									
Decimal Bit	07	06	05	04	03	02	01	00	Size
Octal Bit	07	06	05	04	03	02	01	00	
	Analog Value Channel 1								Read Byte 1
	Analog Value Channel 1								Read Byte 2
	not used								Byte3
	reserved for future use								Byte4
	Analog Value Channel 2								Read Byte 5
	Analog Value Channel 2								Read Byte 6
	not used								Byte7
	reserved for future use								Byte8
	Analog Value Channel 3								Read Byte 9
	Analog Value Channel 3								Read Byte 10
	not used								Byte11
	reserved for future use								Byte12
	Analog Value Channel 4								Read Byte 13
	Analog Value Channel 4								Read Byte 14
	not used								Byte15
	reserved for future use								Byte16
	Analog Value Channel 5								Read Byte 17
	Analog Value Channel 5								Read Byte 18
	not used								Byte19
	reserved for future use								Byte20
	Analog Value Channel 6								Read Byte 21
	Analog Value Channel 6								Read Byte 22
	not used								Byte23
	reserved for future use								Byte24
	Analog Value Channel 7								Read Byte 25
	Analog Value Channel 7								Read Byte 26
	not used								Byte27
	reserved for future use								Byte28
	Analog Value Channel 8								Read Byte 29
	Analog Value Channel 8								Read Byte 30
	not used								Byte31
	reserved for future use								Byte32
Not Used									Write Byte 1

16-Channel Analog Input Module (T1F–16AD–x, T1F–16RTD and T1F–14THM)

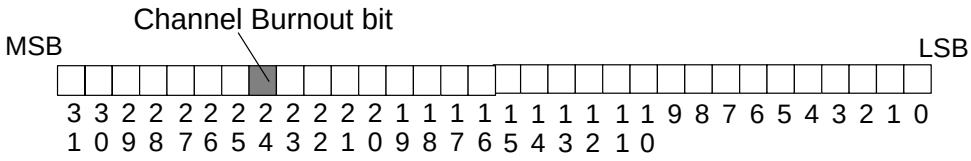
NOTE: Eventhough the T1F–14THM only has 14 channels, the module consumes 16 channels of memory (16 double words). The first 14 channels are used for input data.

Image Table Mapping



T1F–14THM and T1F–16RTD Channel Burnout Bit

NOTE: The T1F–14THM can be configured for Magnitude plus sign bit or 2's complement data format. The T1F–16RTD processes negative temperatures in 2's Complement format only. See the Module Data Sheets in chapter 3 for configuration information.



Memory Map of 16-Channel Analog Input Module									
Decimal Bit	07	06	05	04	03	02	01	00	Size
Octal Bit	07	06	05	04	03	02	01	00	
	Analog Value Channel 1								Read Byte 1
	Analog Value Channel 1								Read Byte 2
	not used								Byte3
	reserved for future use								Byte4
	Analog Value Channel 2								Read Byte 5
	Analog Value Channel 2								Read Byte 6
	not used								Byte7
	reserved for future use								Byte8
	Analog Value Channel 3								Read Byte 9
	Analog Value Channel 3								Read Byte 10
	not used								Byte11
	reserved for future use								Byte12
	Analog Value Channel 4								Read Byte 13
	Analog Value Channel 4								Read Byte 14
	not used								Byte15
	reserved for future use								Byte16
	Analog Value Channel 5								Read Byte 17
	Analog Value Channel 5								Read Byte 18
	not used								Byte19
	reserved for future use								Byte20
	Analog Value Channel 6								Read Byte 21
	Analog Value Channel 6								Read Byte 22
	not used								Byte23
	reserved for future use								Byte24
	Analog Value Channel 7								Read Byte 25
	Analog Value Channel 7								Read Byte 26
	not used								Byte27
	reserved for future use								Byte28
	Analog Value Channel 8								Read Byte 29
	Analog Value Channel 8								Read Byte 30
	not used								Byte31
	reserved for future use								Byte32

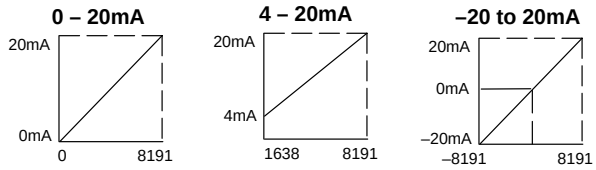
Decimal Bit	07	06	05	04	03	02	01	00	Size
Octal Bit	07	06	05	04	03	02	01	00	
	Analog Value Channel 9								Read Byte 33
	Analog Value Channel 9								Read Byte 34
	not used								Byte35
	reserved for future use								Byte36
	Analog Value Channel 10								Read Byte 37
	Analog Value Channel 10								Read Byte 38
	not used								Byte39
	reserved for future use								Byte40
	Analog Value Channel 11								Read Byte 41
	Analog Value Channel 11								Read Byte 42
	not used								Byte43
	reserved for future use								Byte44
	Analog Value Channel 12								Read Byte 45
	Analog Value Channel 12								Read Byte 46
	not used								Byte47
	reserved for future use								Byte48
	Analog Value Channel 13								Read Byte 49
	Analog Value Channel 13								Read Byte 50
	not used								Byte51
	reserved for future use								Byte52
	Analog Value Channel 14								Read Byte 53
	Analog Value Channel 14								Read Byte 54
	not used								Byte55
	reserved for future use								Byte56
	Analog Value Channel 15								Read Byte 57
	Analog Value Channel 15								Read Byte 58
	not used								Byte59
	reserved for future use								Byte60
	Analog Value Channel 16								Read Byte 61
	Analog Value Channel 16								Read Byte 62
	not used								Byte63
	reserved for future use								Byte64
Not Used									Write Byte 1

Analog Input Module Resolution

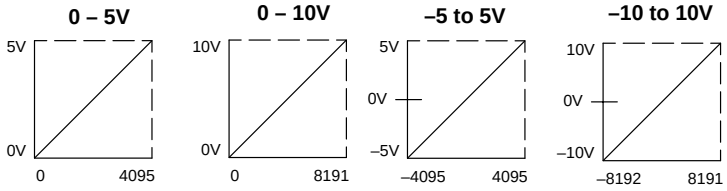
Input Module Resolution

Since the module has 13-bit resolution, the analog signal is converted into 8192 counts ranging from 0-8191 (2^{13}). For example, with a 0 to 10V scale, a 0V signal would be 0, and a 10V signal would be 8191. This is equivalent to a a binary value of 0000 0000 0000 to 0001 1111 1111 1111, or 000 to 1FFF hexadecimal. The following diagram shows how this relates to each signal range.

Current Input Module Resolution



Voltage Input Module Resolution

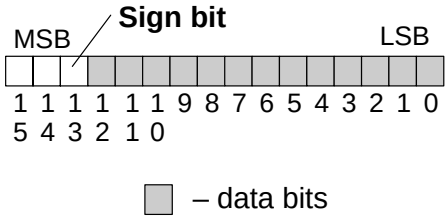


NOTE: The 0 – 5V and –5 to 5V range resolution is 4095, however, if the range is exceeded to 5.5V, for example, the digital input reading will reflect the correct value up to 10V (8191).
The 4 – 20mA range is 1638 to 8191. If the input current signal level falls below 4mA, the correct value will be read down to 0mA.

Channel Data Bits

The first thirteen bits represent the analog data in binary format. The fourteenth bit is the data sign bit.

Bit	Value	Bit	Value
0	1	7	128
1	2	8	256
2	4	9	512
3	8	10	1024
4	16	11	2048
5	32	12	4096
6	64	13	**Sign Bit**



NOTE: Each Analog channel uses 4 bytes. The first and second byte contain the analog data. The third and fourth byte are not used at this time.

Each count can also be expressed in terms of the signal level by using the equation shown. The following table shows the smallest signal levels that will result in a change in the data value for each signal range.

$$\text{SmallestDetectableChange} = \frac{H - L}{\text{Resolution}}$$

H = high limit of the signal range

L = low limit of the signal range

Range	Signal Span (H - L)	Divide By	Smallest Detectable Change
±10V	20 V	16383	1.22 mV
±5V	10 V	8191	1.22 mV
0 to 5V	5 V	4095	1.22 mV
0 to 10V	10 V	8191	1.22 mV
0 to 20mA	20 mA	8191	2.44 μA
4 to 20mA	16 mA	(8191–1638)	2.44 μA
±20mA	40 mA	16383	2.44 μA

Analog and Digital Value Conversions

Sometimes it is helpful to be able to quickly convert between the signal levels and the digital values. This is especially useful during machine startup or troubleshooting. The following table provides formulas to make this conversion easier.

Range	If you know the digital value ...	If you know the signal level ...
–10V to + 10V	$A = \frac{20D}{8191} - 10$	$D = \frac{8191}{20}(A + 10)$
–5V to + 5V	$A = \frac{10D}{4095} - 5$	$D = \frac{4095}{10}(A + 5)$
0 to 5V	$A = \frac{5D}{4095}$	$D = \frac{4095}{5}(A)$
0 to 10V	$A = \frac{10D}{8191}$	$D = \frac{8191}{10}(A)$
0 to 20mA	$A = \frac{20D}{8191}$	$D = \frac{4095}{4}(A)$
4 to 20mA	$A = \frac{16D}{6553}$	$D = \frac{6553}{16}(A)$
–20 mA to + 20mA	$A = \frac{40D}{8191} - 20$	$D = \frac{8191}{40}(A + 20)$

For example, if you are using the –10V to +10V range and you have measured the signal at 6V, you would use the following formula to determine the digital value that should be stored in the V-memory location that contains the data.

$$D = \frac{8191}{20}(A + 10)$$

$$D = \frac{8191}{20}(6V + 10)$$

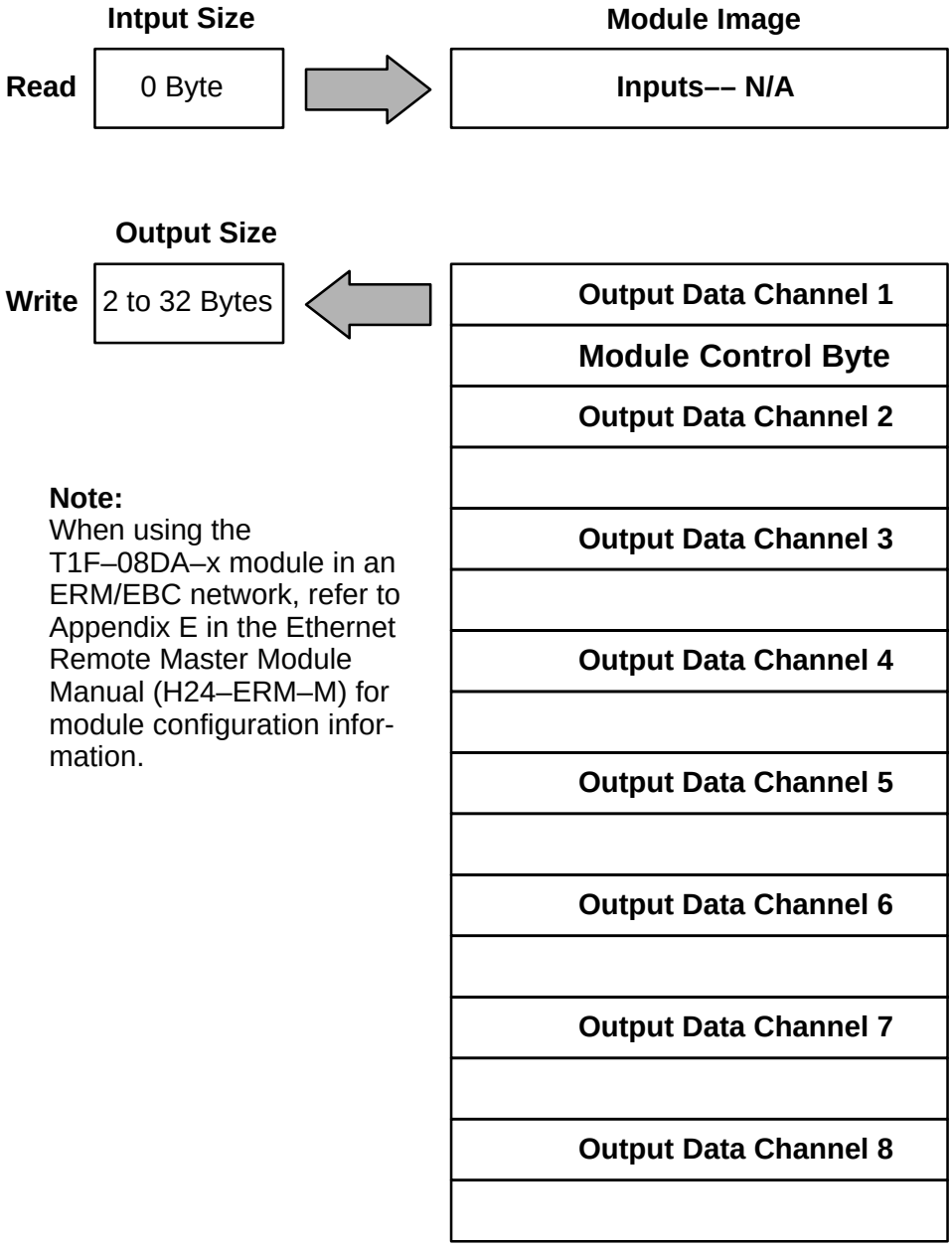
$$D = (409.55)\ (16)$$

$$D = 6552$$

Analog Output Module Memory Map

8-Channel Analog Ouput Module (T1F–08DA–x)

Image Table Mapping

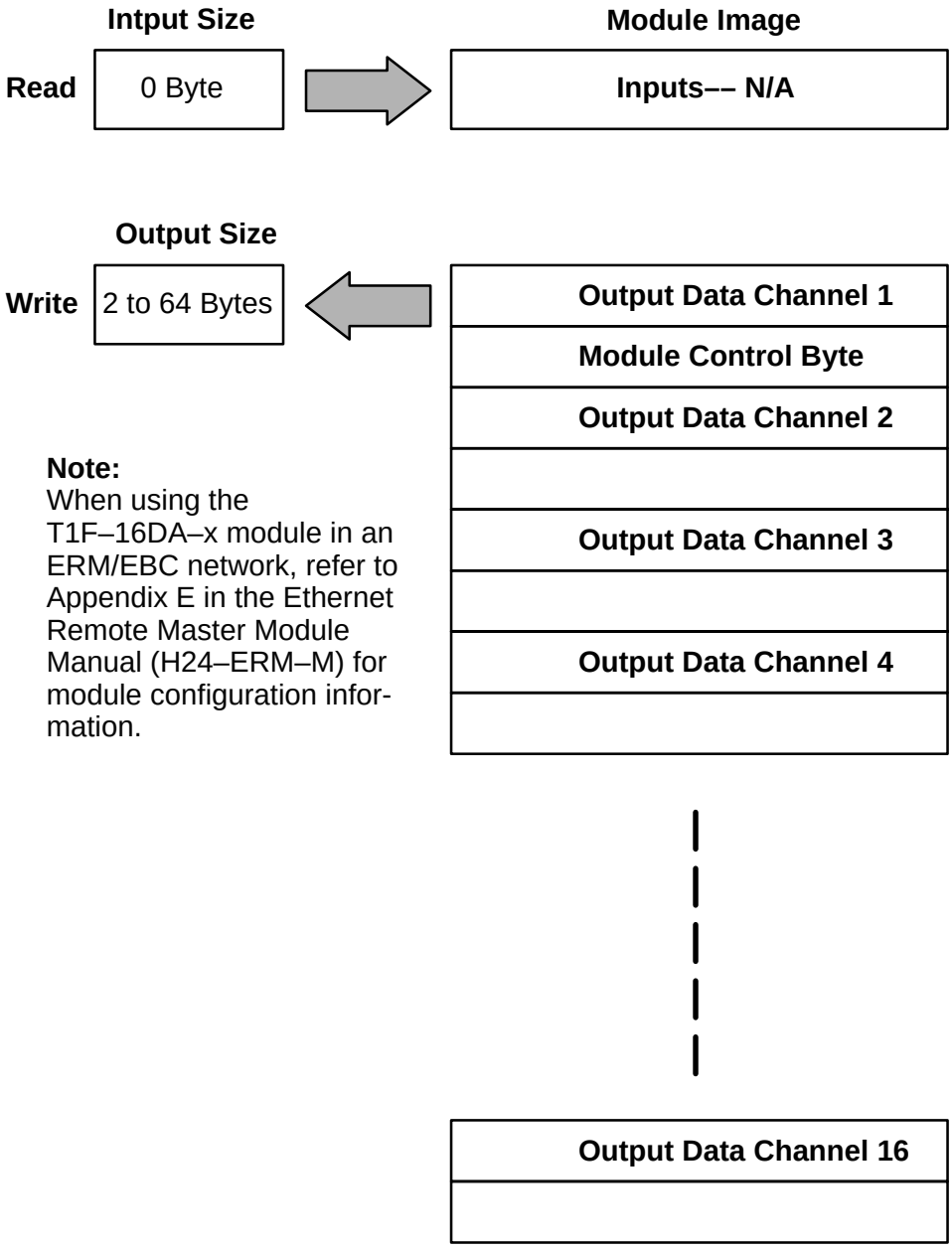


Note:
When using the T1F–08DA–x module in an ERM/EBC network, refer to Appendix E in the Ethernet Remote Master Module Manual (H24–ERM–M) for module configuration information.

Memory Map of 8-Channel Analog Output Module									
Decimal Bit	07	06	05	04	03	02	01	00	Size
Octal Bit	07	06	05	04	03	02	01	00	
Not Used									Read Byte 1
	Analog Value Channel 1								Write Byte 1
	Analog Value Channel 1								Write Byte 2
	not used								Byte3
	Module Control Byte								Write Byte 4
	Analog Value Channel 2								Write Byte 5
	Analog Value Channel 2								Write Byte 6
	not used								Byte7
	reserved for future use								Byte8
	Analog Value Channel 3								Write Byte 9
	Analog Value Channel 3								Write Byte 10
	not used								Byte11
	reserved for future use								Byte12
	Analog Value Channel 4								Write Byte 13
	Analog Value Channel 4								Write Byte 14
	not used								Byte15
	reserved for future use								Byte16
	Analog Value Channel 5								Write Byte 17
	Analog Value Channel 5								Write Byte 18
	used not								Byte19
	reserved for future use								Byte20
	Analog Value Channel 6								Write Byte 21
	Analog Value Channel 6								Write Byte 22
	not used								Byte23
	reserved for future use								Byte24
	Analog Value Channel 7								Write Byte 25
	Analog Value Channel 7								Write Byte 26
	not used								Byte27
	reserved for future use								Byte28
	Analog Value Channel 8								Write Byte 29
	Analog Value Channel 8								Write Byte 30
	not used								Byte31
	reserved for future use								Byte32

16-Channel Analog Ouput Module (T1F–16DA–x)

Image Table Mapping



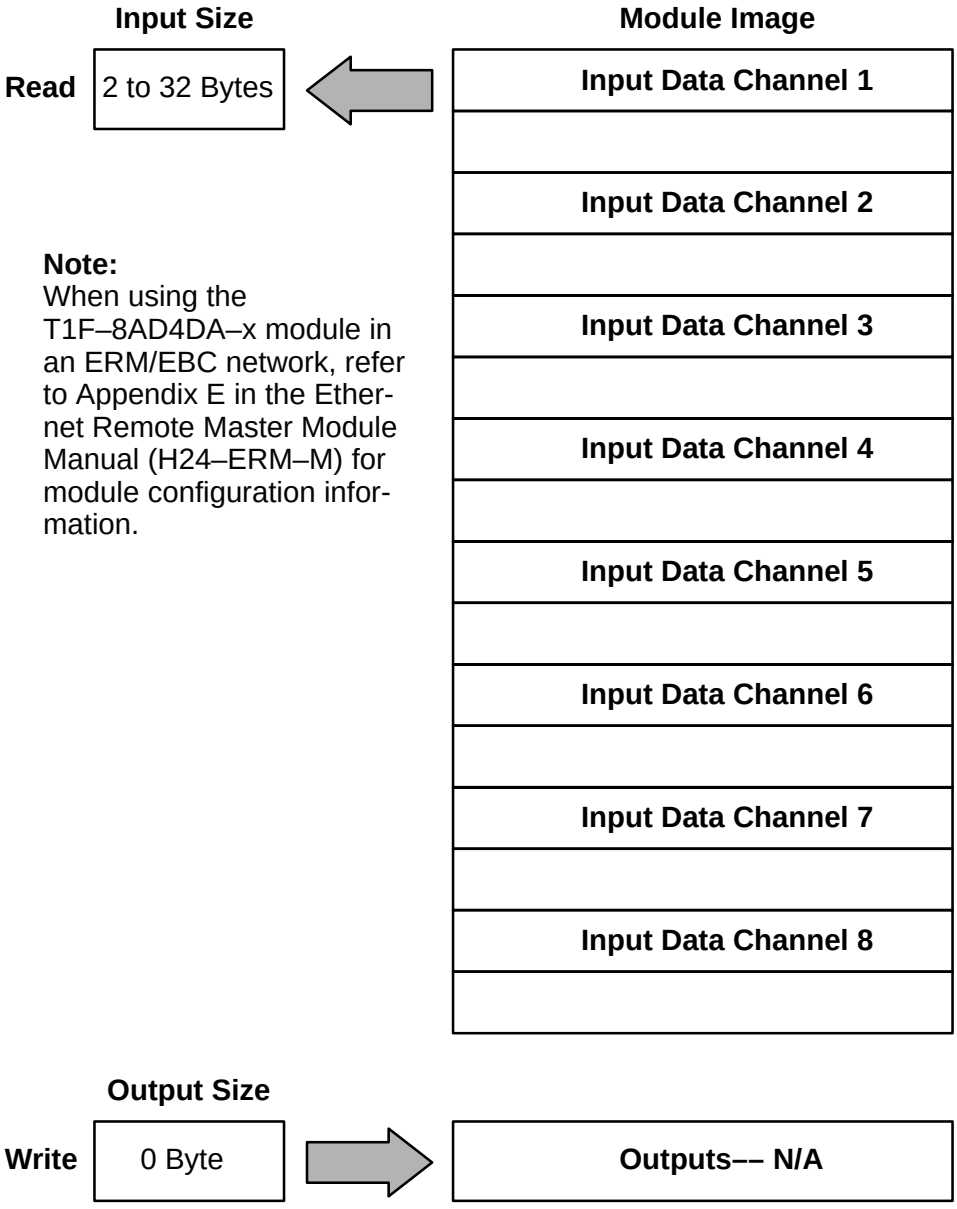
Note:
When using the T1F–16DA–x module in an ERM/EBC network, refer to Appendix E in the Ethernet Remote Master Module Manual (H24–ERM–M) for module configuration information.

Memory Map of 16-Channel Analog Output Module									
Decimal Bit	07	06	05	04	03	02	01	00	Size
Octal Bit	07	06	05	04	03	02	01	00	
Not Used									Read Byte 1
	Analog Value Channel 1								Write Byte 1
	Analog Value Channel 1								Write Byte 2
	not used								Byte3
	Module Control Byte								Write Byte 4
	Analog Value Channel 2								Write Byte 5
	Analog Value Channel 2								Write Byte 6
	not used								Byte7
	reserved for future use								Byte8
	Analog Value Channel 3								Write Byte 9
	Analog Value Channel 3								Write Byte 10
	not used								Byte11
	reserved for future use								Byte12
	Analog Value Channel 4								Write Byte 13
	Analog Value Channel 4								Write Byte 14
	not used								Byte15
	reserved for future use								Byte16
	Analog Value Channel 5								Write Byte 17
	Analog Value Channel 5								Write Byte 18
	not used								Byte19
	reserved for future use								Byte20
	Analog Value Channel 6								Write Byte 21
	Analog Value Channel 6								Write Byte 22
	not used								Byte23
	reserved for future use								Byte24
	Analog Value Channel 7								Write Byte 25
	Analog Value Channel 7								Write Byte 26
	not used								Byte27
	reserved for future use								Byte28
	Analog Value Channel 8								Write Byte 29
	Analog Value Channel 8								Write Byte 30
	not used								Byte31
	reserved for future use								Byte32

Decimal Bit	07	06	05	04	03	02	01	00	Size
Octal Bit	07	06	05	04	03	02	01	00	
	Analog Value Channel 9								Write Byte 33
	Analog Value Channel 9								Write Byte 34
	not used								Byte35
	reserved for future use								Byte36
	Analog Value Channel 10								Write Byte 37
	Analog Value Channel 10								Write Byte 38
	not used								Byte39
	reserved for future use								Byte40
	Analog Value Channel 11								Write Byte 41
	Analog Value Channel 11								Write Byte 42
	not used								Byte43
	reserved for future use								Byte44
	Analog Value Channel 12								Write Byte 45
	Analog Value Channel 12								Write Byte 46
	not used								Byte47
	reserved for future use								Byte48
	Analog Value Channel 13								Write Byte 49
	Analog Value Channel 13								Write Byte 50
	not used								Byte51
	reserved for future use								Byte52
	Analog Value Channel 14								Write Byte 53
	Analog Value Channel 14								Write Byte 54
	not used								Byte55
	reserved for future use								Byte56
	Analog Value Channel 15								Write Byte 57
	Analog Value Channel 15								Write Byte 58
	not used								Byte59
	reserved for future use								Byte60
	Analog Value Channel 16								Write Byte 61
	Analog Value Channel 16								Write Byte 62
	not used								Byte63
	reserved for future use								Byte64

8-Channel Analog Input / 4–Channel Analog Output Module (T1F–8AD4DA–x)

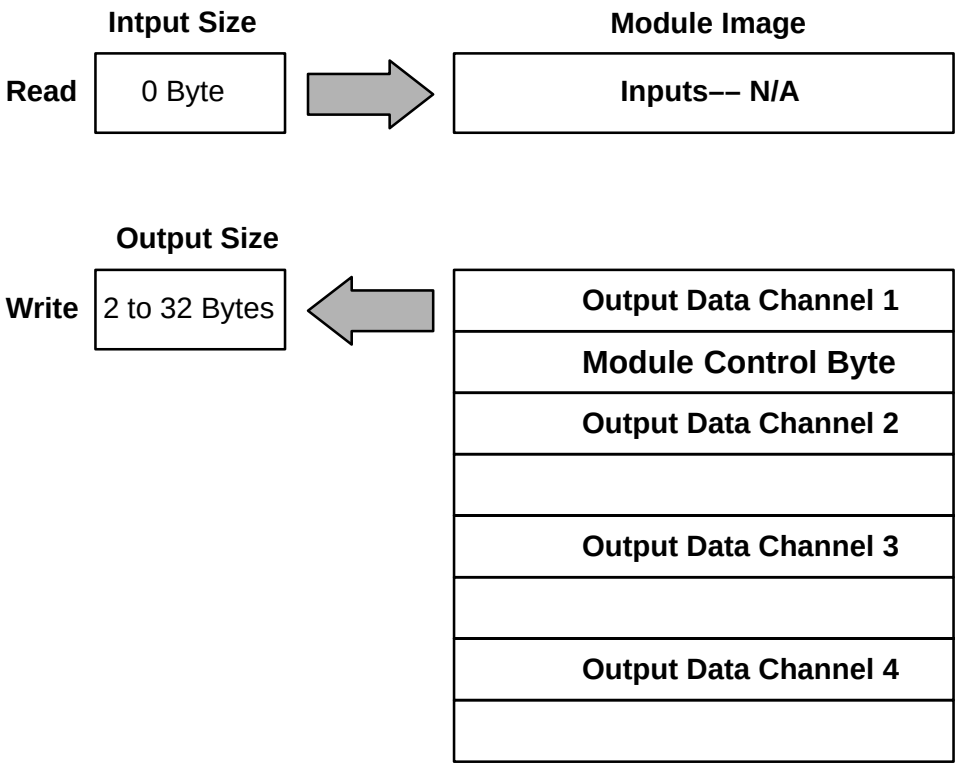
Input Image Table Mapping



Note:
When using the T1F–8AD4DA–x module in an ERM/EBC network, refer to Appendix E in the Ethernet Remote Master Module Manual (H24–ERM–M) for module configuration information.

8-Channel Analog Input / 4–Channel Analog Output Module (T1F–8AD4DA–x)

Output Image Table Mapping



Memory Map of the 8 Analog Input Channels of the T1F–8AD4DA–x									
Decimal Bit	07	06	05	04	03	02	01	00	Size
Octal Bit	07	06	05	04	03	02	01	00	
	Analog Value Channel 1								Read Byte 1
	Analog Value Channel 1								Read Byte 2
	not used								Byte3
	reserved for future use								Byte4
	Analog Value Channel 2								Read Byte 5
	Analog Value Channel 2								Read Byte 6
	not used								Byte7
	reserved for future use								Byte8
	Analog Value Channel 3								Read Byte 9
	Analog Value Channel 3								Read Byte 10
	not used								Byte11
	reserved for future use								Byte12
	Analog Value Channel 4								Read Byte 13
	Analog Value Channel 4								Read Byte 14
	not used								Byte15
	reserved for future use								Byte16
	Analog Value Channel 5								Read Byte 17
	Analog Value Channel 5								Read Byte 18
	not used								Byte19
	reserved for future use								Byte20
	Analog Value Channel 6								Read Byte 21
	Analog Value Channel 6								Read Byte 22
	not used								Byte23
	reserved for future use								Byte24
	Analog Value Channel 7								Read Byte 25
	Analog Value Channel 7								Read Byte 26
	not used								Byte27
	reserved for future use								Byte28
	Analog Value Channel 8								Read Byte 29
	Analog Value Channel 8								Read Byte 30
	not used								Byte31
	reserved for future use								Byte32
Not Used									Write Byte 1

Memory Map of the 4 Analog Output Channels of the T1F–8AD4DA–x									
Decimal Bit	07	06	05	04	03	02	01	00	Size
Octal Bit	07	06	05	04	03	02	01	00	
Not Used									Read Byte 1
	Analog Value Channel 1								Write Byte 1
	Analog Value Channel 1								Write Byte 2
	not used								Byte3
	Module Control Byte								Write Byte 4
	Analog Value Channel 2								Write Byte 5
	Analog Value Channel 2								Write Byte 6
	not used								Byte7
	reserved for future use								Byte8
	Analog Value Channel 3								Write Byte 9
	Analog Value Channel 3								Write Byte 10
	not used								Byte11
	reserved for future use								Byte12
	Analog Value Channel 4								Write Byte 13
	Analog Value Channel 4								Write Byte 14
	not used								Byte15
	reserved for future use								Byte16

Analog Output Module Control Byte

Channel 1 Memory Map of 8&16-Channel Analog Output Module									
Decimal Bit	07	06	05	04	03	02	01	00	Size
Octal Bit	07	06	05	04	03	02	01	00	
	Analog Value Channel 1								Write Byte 1
	Analog Value Channel 1								Write Byte 2
	not used								Byte3
	Module Control Byte								Write Byte 4

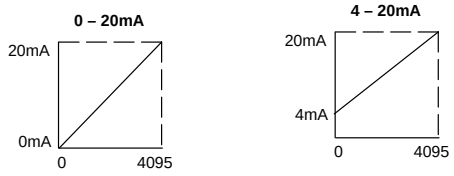
Module Control Byte of 8&16-Channel Analog Output Module									
Decimal Bit	31	30	29	28	27	26	25	24	Read/Write
Octal Bit	37	36	35	34	33	32	31	30	
Bit 24	**Outputs Enable** 0 = All outputs OFF 1 = All outputs Enabled								Write
Bit 25	**Unipolar / Bipolar** 0 = Unipolar selected 1 = Bipolar selected								Write
Bit 26	**5V / 10V Range** 0 = 5V range 1 = 10V range								Write
Bit 27	**0 – 20mA / 4–20mA Range** 0 = 0 – 20mA range 1 = 4 – 20mA range								Write
Bit 28 – 31	Reserved for system use								–

Analog Output Module Resolution

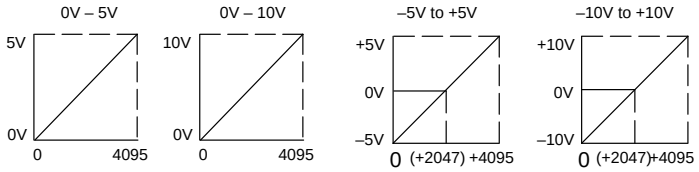
Ouput Module Resolution

Since the module has 12-bit resolution, the analog signal is converted into 4096 counts ranging from 0-4095 (2^{12}). For example, with a 0 to 10V scale, a 0V signal would be 0, and a 10V signal would be 4095. This is equivalent to a a binary value of 0000 0000 0000 to 1111 1111 1111, or 000 to FFF hexadecimal. The following diagram shows how this relates to each signal range.

Current Output Module Resolution



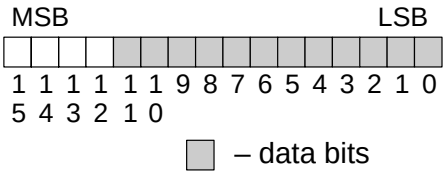
Voltage Output Module Resolution



Channel Data Bits

The first twelve bits represent the analog data in binary format.

Bit	Value	Bit	Value
0	1	6	64
1	2	7	128
2	4	8	256
3	8	9	512
4	16	10	1024
5	32	11	2048



NOTE: Each Analog channel uses 4 bytes. The first and second byte contain the analog data. The third and fourth byte are not used at this time.

Each count can also be expressed in terms of the signal level by using the equation shown. The following table shows the smallest signal levels that will result in a change in the data value for each signal range.

$$\text{SmallestDetectableChange} = \frac{H - L}{\text{Resolution}}$$

H = high limit of the signal range

L = low limit of the signal range

Range	Signal Span (H - L)	Divide By	Smallest Detectable Change
±10V	20 V	4095	4.88 mV
±5V	10 V	4095	2.44 mV
0 to 5V	5 V	4095	1.22 mV
0 to 10V	10 V	4095	2.44 mV
0 to 20mA	20 mA	4095	4.88 μA
4 to 20mA	16 mA	4095	3.91 μA

Analog and Digital Value Conversions

ometimes it is helpful to be able to quickly convert between the voltage or current signal levels and the digital values. This is especially helpful during machine startup or troubleshooting. The following table provides formulas to make this conversion easier.

Range	If you know the digital value ...	If you know the analog signal level ...
0 to 5V	$A = \frac{5D}{4095}$	$D = \frac{4095}{5}(A)$
0 to 10V	$A = \frac{10D}{4095}$	$D = \frac{4095}{10}(A)$
±5V	$A = \frac{10D}{4095} - 5$	$D = \frac{4095}{10}(A + 5)$
±10V	$A = \frac{20D}{4095} - 10$	$D = \frac{4095}{20}(A + 10)$
0 to 20mA	$A = \frac{20D}{4095}$	$D = \frac{4095}{20}(A)$
4 to 20mA	$A = \frac{16D}{4095} + 4$	$D = \frac{4095}{16}(A - 4)$

For example, if you are using the –10 to +10V range and you know you need a 6V signal level, you would use the following formula to determine the digital value that should be stored in the V-memory location that contains the data.

$$D = \frac{4095}{20}(A + 10)$$

$$D = \frac{4095}{20}(6V + 10)$$

$$D = (204.75)\ (16)$$

$$D = 3276$$