

#### FEATURES

- 1:36 speed ratio
- 20-second accuracy
- Optional binary speed ratios (1:16 or 1:32)
- Single low profile module
- Over-voltage and transient protection
- High input impedance
- No external transformer modules required
- High speed tracking
- Industry standard pinouts

#### APPLICATIONS

Ordnance Control — Radar Tracking Systems —  
Navigation Systems — Collision Avoidance Systems

2-15

#### GENERAL DATA

The Series 168M500 is a complete two-speed, high performance, synchro (or resolver) to digital converter packaged in a single low profile module. Module includes two-speed combining, crossover network and stickoff circuits necessary for two speed conversion. Units can be specified over the frequency ranges of either 47 to 3000 Hz or 350 to 3000 Hz. The 168M500 is a pin-for-pin replacement for the DDC Model SDC-361, CSI Model 168H500, et al.

Typical of tracking-type converters, two-speed synchro (or resolver) input data is accurately and continuously converted into a single 16 bit digital word with no velocity induced errors at up to specified tracking rates.

All units are completely trimmed and adjustment-free, allowing absolute interchangeability. Reliability is assured by the use of high grade components rigidly encapsulated and electrically stressed to the lowest possible levels.

#### THEORY OF OPERATION

The theory of operation for a single-speed tracking synchro to digital (S/D) converter is explained first. The same principles apply for a resolver to digital converter.

##### Single-Speed Converter (See Figure 1)

The S/D converter determines the value of the input angle  $\phi$  by comparing a digital feedback angle  $\Theta$  with the synchro input angle. When the difference between the input angle and the feedback angle is zero, the output angle contained in the up-down counter is equal to the synchro input angle.

The Function Generator performs the trigonometric computation:  $\sin(\phi - \Theta) = (\sin\phi\cos\Theta - \cos\phi\sin\Theta)$ .

Note that for small angles,  $\sin(\phi - \Theta) \cong (\phi - \Theta)$ . The equality given by the above equation is true only in the first quadrant, i.e.,  $0^\circ$  to  $90^\circ$ . The analog inputs to the Function Generator have different values depending on the quadrant in which the input angle lies.

$\phi - \Theta$  is an analog representation of the error between  $\phi$  the input angle, and  $\Theta$  the output angle. This analog error is first demodulated then fed to an analog integrator whose output controls the frequency of a voltage-controlled oscillator (VCO). The VCO clocks the up-down counter. The up-down counter is functionally an integrator, therefore the tracking converter in itself is a closed-loop servo mechanism with two lags, making it a "Type II" servo loop. The "Type II" servo loop tracking converter exhibits no velocity errors and only minor acceleration errors.

##### Two-Speed Converter (See Figure 2)

The operation of a two-speed S/D converter is essentially the same as the single speed except there are two solid state CT's (SSCT) generating two error voltages. Assuming an off-null condition (the input angle does not equal the output angle), the crossover detector feeds the coarse (1X) SSCT error signal output to the demodulator. As the output angle  $\Theta$  approaches the input angle  $\phi$  the coarse SSCT output approaches a null. When the coarse SSCT output drops below a preset threshold, the crossover detector switches the fine (36X) SSCT error signal into the demodulator. The feedback angle  $\Theta$  to the fine SSCT is multiplied by the speed ratio (in this case 36); the gradient of the fine SSCT then is 36X the coarse SSCT. The servo loop then is able to seek an even finer null. The converter will continue to use the fine error signal for continuous tracking. In order to eliminate false stable nulls of  $180^\circ$ , an angle offset produced by the Digital Adder and stickoff voltage (SO) is introduced into the coarse SSCT.

**ELECTRICAL SPECIFICATIONS**

Parameter	Value	
Resolution	16 bits (0.0055°)	
Accuracy <sup>(1)</sup>	20 seconds (1:32 or 1:36) 40 seconds (1:16)	
Speed ratio	1:16, 1:32, 1:36	
Allowable Synchro <sup>(2)</sup> Misalignment	± 2°	
Synchro Input <sup>(3)</sup> Rates	47 to 3000 Hz	350 to 3000 Hz
Maximum Tracking Rate	250°/sec	1000°/sec
Acceleration Constant (Ka)	4,500 sec <sup>-2</sup>	70,000 sec <sup>-2</sup>
Power Supplies <sup>(4)</sup>		
+ 15V	60mA max (50mA typ)	
- 15V	60mA max (50mA typ)	
+ 5V	5mA max (2mA typ)	
Digital Inputs/Outputs		
Parallel Binary Angle	2 TTL loads	
Converter Busy (CB)	3μs max positive pulse 7μs max (168M502) 2 TTL loads max	
Built-In Test (BIT)	Logic "0" = normal tracking Logic "1" = not tracking; 2 TTL loads	
Inhibit (INH)	Logic "0" inhibits 0.4 Std TTL load plus 51 kohm pull-up to + 5V	
Velocity Output		
Scale Factor	± 1.0V ± 20% for 100°/sec @ 400 Hz ± 1.0V ± 20% for 25°/sec @ 60 Hz	
Range	± 10V min	
Loading	10 kohms max	
Synchro/Resolver Input <sup>(5)</sup>		
11.8V L-L	75 kohms min	
90V L-L	600 kohms min	
Reference Input <sup>(6)</sup>		
23 to 29V Rms	180 kohms min	
103 to 127V Rms	800 kohms min	
Input Type <sup>(6)</sup>	Solid state differential	
Temperature Ranges		
Operating	0° to 70°C	
Storage	- 55° to + 125°C	
Dimensions	3.125" x 2.625" x 0.4"	
Weight	3.5 oz	

**NOTES:**

- (1) Accuracy applies for:
  - (a) ± 10% signal amplitude variations
  - (b) 10% harmonic distortion in the reference
  - (c) over power supply range
  - (d) over operating temperature range
- (2) With two-speed synchro converters, it is important to understand that the output of the fine synchro dominates in the determination of the coarse shaft angle despite any misalignment of the two synchros. No ambiguities will exist unless the allowable misalignment is exceeded.
- (3) Higher tracking and acceleration rates available; consult factory.
- (4) All units can operate on voltages between ± 11.5V to ± 16.5V. The tolerance on the + 5V supply is ± 5%.
- (5) Other voltages available; consult factory.
- (6) Any one stator and/or rotor line may be grounded. Common mode voltages up to specified L-L voltage have no effect on operation.

**DIGITAL INPUTS/OUTPUTS**

Logic outputs are high speed CMOS and can drive remote loads. The Inhibit is a CMOS input with a 51 kohm pull-up resistor to + 5V.

The BIT logic output is a built-in test derived from the crossover detector. Whenever the digital output is not tracking the synchro or resolver input within the fine speed range the BIT output goes to logic '1'.

**TIMING**

Whenever an input angle change occurs, the converter changes the digital angle in steps of 1 LSB and generates a converter busy (CB) pulse. During the CB pulse, the output data is changing and should not be transferred. The converter will delay an inhibit command applied during the CB interval. There are two methods of interfacing with a computer: (1) synchronously or (2) asynchronously. A simple method of synchronously loading is to: (a) apply the Inhibit, (b) wait a busy interval, (c) transfer data, and (d) release Inhibit. Asynchronously loading is accomplished by transferring data on the trailing edge of the CB pulse.

**ANALOG VELOCITY OUTPUT**

VEL is a DC voltage proportional to the angular velocity of the synchro or resolver shaft. Voltage polarity is positive for an increasing digital angle and negative for a decreasing digital angle. Other characteristics are listed in the specifications table.

**DYNAMIC PERFORMANCE**

The 168M500 series employs a Type II servo loop ( $K_v = \infty$ ) and very high acceleration constants (Ka). The loop dynamics are completely independent of power supply variations over their specific ranges. As long as the maximum tracking rate is not exceeded there will be no velocity lag and only minor acceleration lags in the converter output.

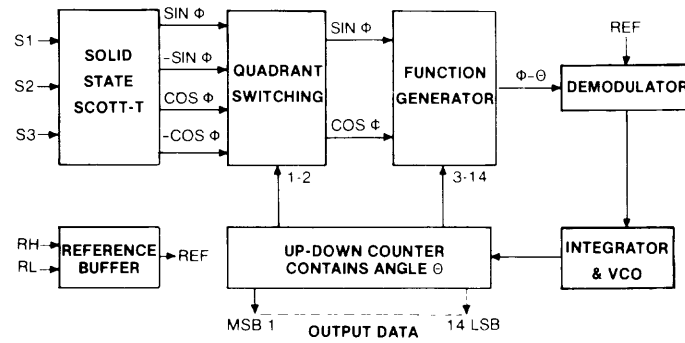
The open loop transfer functions for both frequency options are given below:

$$G_{60} = \frac{70^2 \left( \frac{S}{50} + 1 \right)}{S^2 \left( \frac{S}{200} + 1 \right)} \quad G_{400} = \frac{266^2 \left( \frac{S}{178} + 1 \right)}{S^2 \left( \frac{S}{666} + 1 \right)}$$

## BLOCK DIAGRAMS

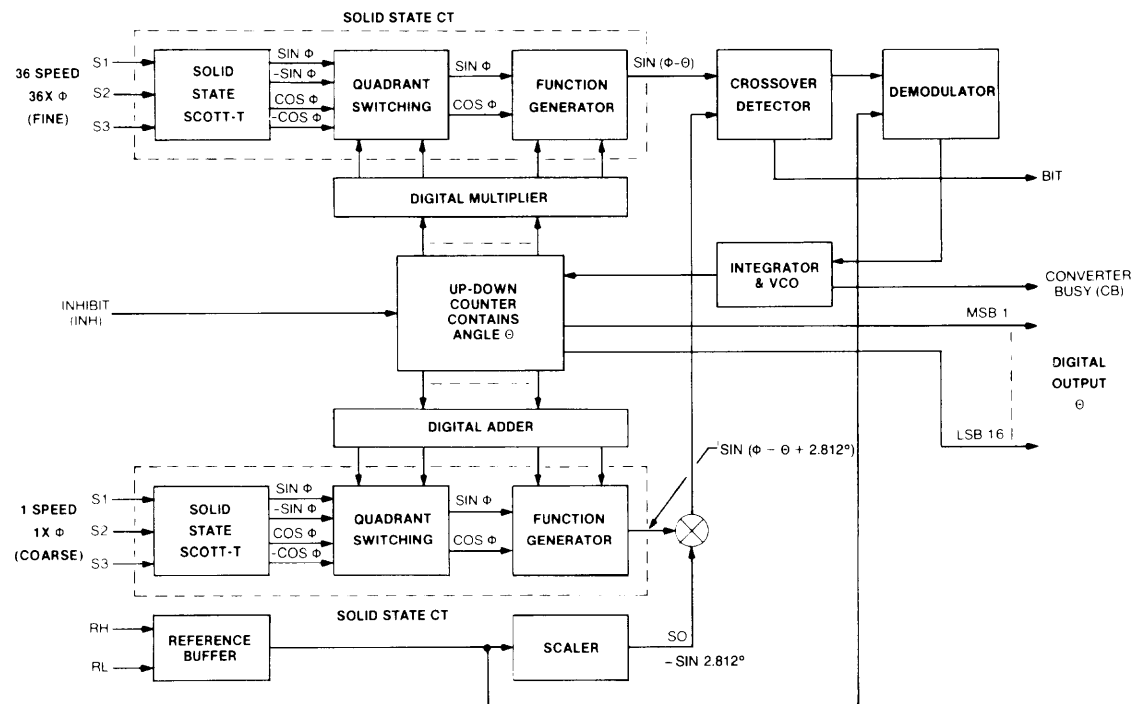
### SINGLE-SPEED CONVERTER

Figure 1

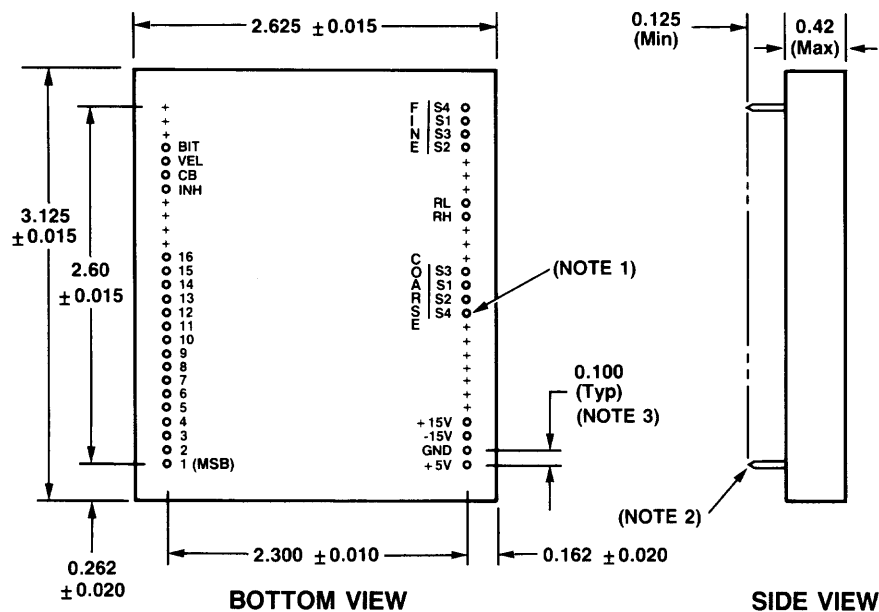


### TWO-SPEED CONVERTER

Figure 2



# MECHANICAL OUTLINE



## NOTES:

1. S4 pin appears on resolver input model only.
2. Rigid 0.025 diameter pins for solder-in or plug-in applications.
3. Noncumulative.
4. Dimensions are in inches unless otherwise specified.

## BIT WEIGHT TABLE

Bit	Deg/Bit	Min/Bit
1 MSB	180	10,800
2	90	5,400
3	45	2,700
4	22.5	1,350
5	11.25	675
6	5.625	337.5
7	2.813	108.75
8	1.406	84.38
9	0.703	42.19
10	0.3516	21.09
11	0.1758	10.55
12	0.0879	5.27
13	0.0439	2.64
14	0.0220	1.32
15	0.0110	0.66
16	0.0055	0.33

## ORDERING INFORMATION

168M Suffix	Input Type	Stator Voltage	Reference Voltage	Fre- quency	Speed Ratio
500	Synchro	11.8V	26V	400 Hz	1:36
501	Synchro	90V	115V	400 Hz	1:36
502	Synchro	90V	115V	60 Hz	1:36
503	Resolver	11.8V	26V	400 Hz	1:36

## NOTES:

1. Standard temperature range  $0^{\circ}$  to  $70^{\circ}\text{C}$ .
2. Standard speed ratio is 1:36; for 1:16 or 1:32, add suffix - 16 or - 32 to part number.