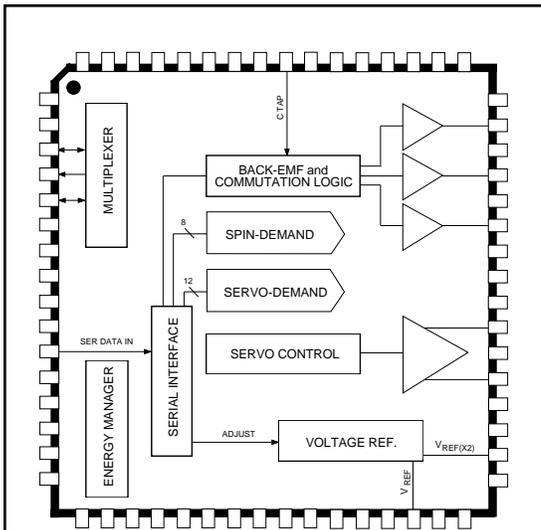


# *SUPER*SERVO<sup>TM</sup> SPINDLE & VOICE-COIL ACTUATION MANAGER/DRIVER



Dwg. PP-048

## ABSOLUTE MAXIMUM RATINGS

at  $T_A = +25^\circ\text{C}$

Load Supply Voltage, $V_{CC(PWR)}$ .....	<b>7.0 V</b>
Spindle Output Current, $I_{OUT(S)}$ .....	<b><math>\pm 1.6</math> A</b>
Voice-Coil Output Current, $I_{OUT(S)}$ .....	<b><math>\pm 0.9</math> A</b>
Output Current, $I_{OUT(S)}$ .....	<b><math>\pm 1.6</math> A</b>
Logic Supply Voltage $V_{CC(D)}$ .....	<b>6.0 V</b>
Operating Temperature Range, $T_A$ .....	<b><math>0^\circ\text{C}</math> to <math>+70^\circ\text{C}</math></b>

Output current rating may be restricted to a value determined by system concerns and factors. These include: system duty cycle and timing, ambient temperature, and use of any heatsinking and/or forced cooling.

The A8980CJT provides complete drive, management, and control of the voice-coil and spindle motor power actuation subsystems used in hard disk drives. Extensive programmable control features and system diagnostics are provided via a serial interface under the direction of an external microcontroller. The large-scale integration and use of advanced DABiC<sup>TM</sup> (digital/analog-BiCMOS) merged technologies results in minimum power dissipation, minimum operating voltage requirements, and minimum external components.

The spindle drive function incorporates a three-phase MOS power driver and a back-EMF sensing motor commutation scheme. Internal logic and analog circuitry provide complete start-up and  $\mu\text{C}$ -assisted run modes without the need for snubbers or other external components. Additional headroom is achieved by a proprietary circuit, which eliminates the need for an external current-sense resistor. Intrinsic ground clamp and flyback diodes are also provided.

The voice-coil function contains a 12-bit DAC, tunable low-pass and notch filters, and a full-bridge power driver. The MOS outputs provide increased available voltage and lower power dissipation over bipolar devices. Voice-coil current is sensed by internal circuitry that eliminates the need for an external current-sense resistor. Additional internal circuitry can be configured to provide an over-velocity fault limit by utilizing the internally monitored current of the voice-coil motor.

The spindle and voice-coil control functions are supplemented by an ENERGY MANAGER<sup>TM</sup> subsystem, which efficiently channels available power to protect the heads and the data disk during system failure or normal system shutdown. Synchronous rectification of spindle back-EMF voltage provides nearly lossless conversion of spindle rotational inertia into power to operate the voice coil motor for parking the heads. A dc-to-dc converter provides continuous operation at minimum supply voltages. In addition, the ENERGY MANAGER subsystem provides several sleep modes and latched fault states for undervoltage or thermal faults.

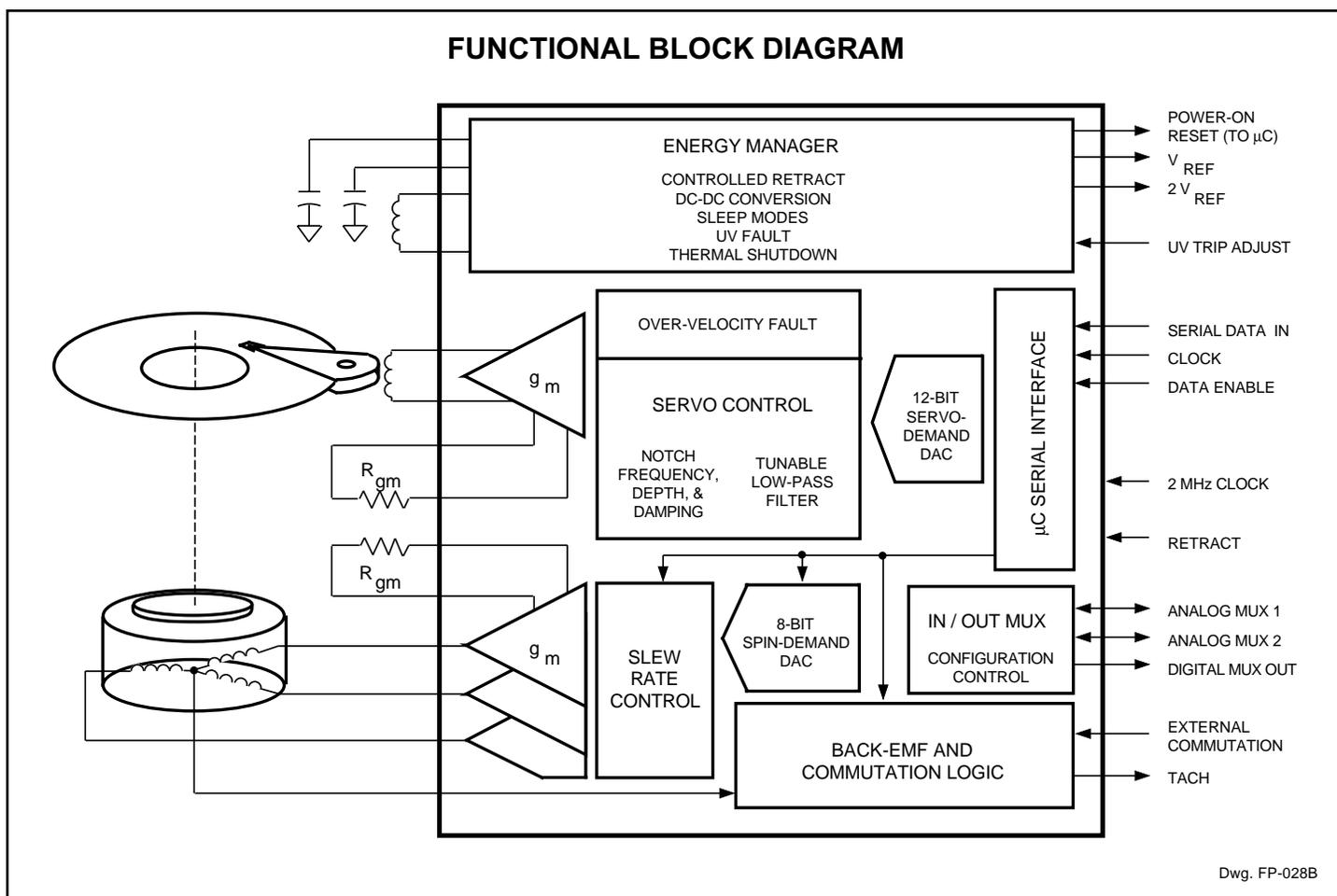
The A8980CJT is supplied in a 64-lead thin quad flatpack for surface-mount applications.

## FEATURES

### Voice Coil Motor Driver:

- Low  $r_{DS(on)}$  MOS Outputs
- Lossless Current Sensing
- Zero Deadband
- User-Adjustable Transconductance Gain
- Retract Circuitry Functional to 0 V

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#### Spindle Motor Controller/Driver:

- Low  $r_{DS(on)}$  MOS Outputs
- Back-EMF Circuitry Eliminates Hall-Effect Sensors
- Programmable Slew Rate Eliminates Snubbers
- Lossless Current Sensing
- Improved Speed Disturbance Performance
- Dynamic Braking with Delay
- Active Braking

#### Servo Compensator/Notch:

- Over-Velocity Fault Circuitry
- 12-Bit Servo-Demand DAC
- Programmable Complex Pole Low-pass-Filter
- Programmable Notch Frequency, Depth, and Damping

#### Energy Manager:

- 3.0 V to 5.5 V Operation
- Independent Power-Down (Sleep) Modes for all Functional Blocks
- Efficient Synchronous Rectification Supplies Power During Blackout
- Thermal Fault Shutdown Circuitry
- Trimmed Bandgap Voltage Reference
- Smart DAC Reference Generator
- Programmable Voltage Reference for Relative Ground
- Over-Velocity Fault Circuitry
- Supply Under-Voltage Monitor with Adjustable Trip Point
- System Diagnostics Data Out
- Power-On Reset Generator



## FUNCTIONAL DESCRIPTION

## ACTUATOR

**Servo-Demand DAC.** A 12-bit DAC is provided to bridge the DSP “soft” domain to the analog hardware domain. The term “demand” refers to the distinction between the newly requested voice-coil current and the prior current being supplied. The DAC, operating in straight binary format, spans the full dynamic range between a large signal velocity and a precision position mode. The DAC output is updated synchronously with the notch functions to avoid the creation of aliasing products.

**Low-Pass Filter.** This double, non-intrinsic complex-pole low-pass filter is provided to attenuate undesirable, out-of-band information. The input of this discrete time filter is sampled synchronously with the 12-bit DAC and notch function in order to avoid aliasing products.

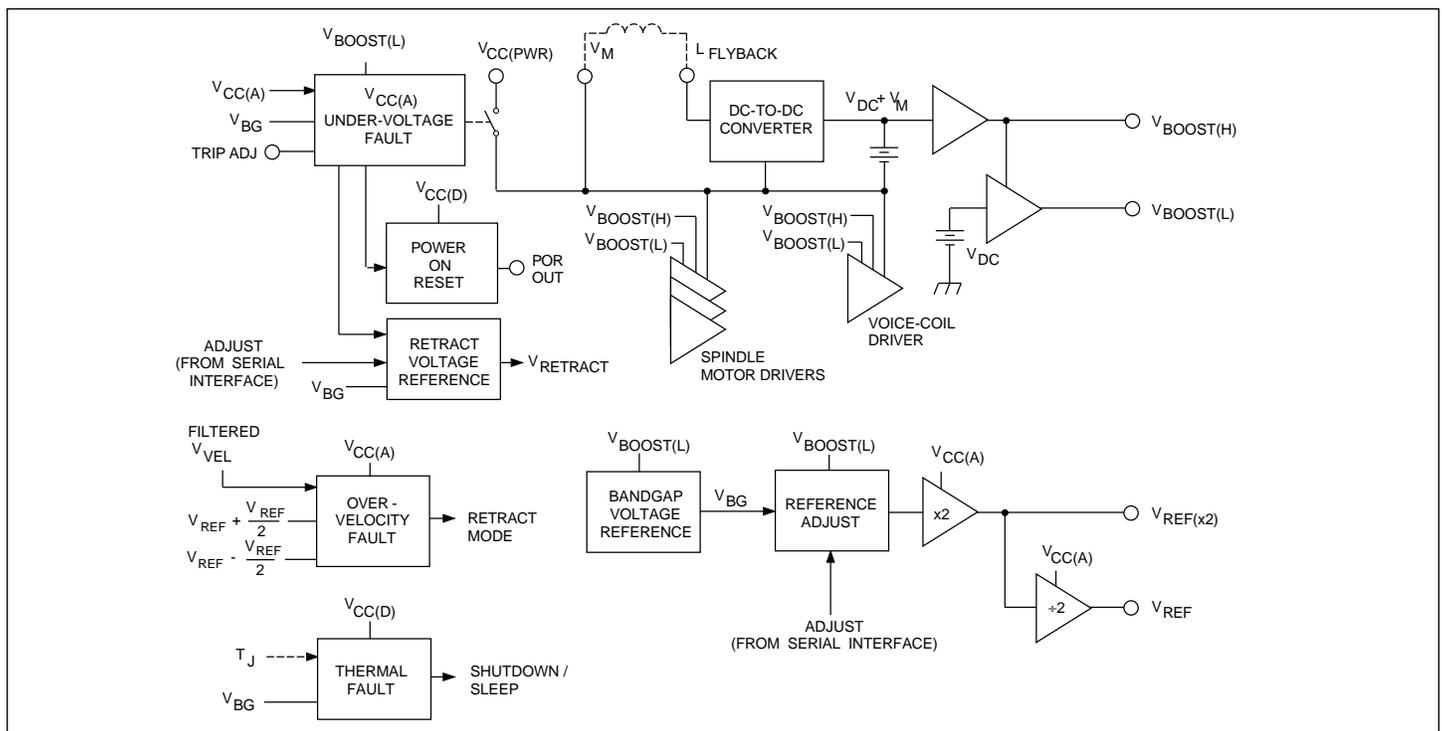
**Notch Filter.** This notch filter has a programmable center frequency and programmable notch depth to provide truly independent control of notch damping. Enough range and granularity are provided to allow versatile and accurate out-of-band attenuation of undesirable energy sources.

**Actuator Transconductance Amplifier.** The final transconductance function of the voice-coil actuation signal path is achieved by monitoring the load current and generating an error voltage to drive a local  $g_m$  amplifier control loop. The error voltage is scaled by an external precision resistor ( $R_{g_m(Act)}$ ). This resistor does not carry load current and is intended only for accurate determination of the transconductance. The function is:

$$g_{m(Act)} = \frac{5800}{R_{g_m(Act)}} \text{ A/V}$$

$$\text{and } I_{OUT} = V_{SERVO} \cdot g_{m(Act)}$$

**Actuator Power Outputs.** The voice-coil output driver is a full-bridge power driver operating in a class-B mode. The power output devices are enhancement-mode MOS transistors. Special internal circuitry results in nearly zero cross-over distortion when switching from one source/sink pair to another.



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## SPINDLE

The spindle function is a three-phase back-EMF sensing motor controller and driver. During start-up, internal circuitry provides complete spindle control and drive. At speed however, an external microcontroller is used to provide speed (phase/frequency) detection as well as compensation.

## ENERGY MANAGER

The management of available energy is provided by automatic operating modes evoked by the fault monitor or sleep-mode manager. The fault monitor consists of an over-velocity fault circuit, a  $V_{CC(A)}$  under-voltage fault circuit, and a thermal fault circuit. The operating modes include  $V_{CC(PWR)}$  isolation, active rectification of spindle back-EMF voltage to provide nearly lossless conversion of spindle rotational inertia into power to operate the voice-coil motor for parking the

heads, actuator retract mode controlled by constant voltage, and several sleep modes. In addition, a power-on reset function and two programmable voltage references ( $V_{REF}$  and  $V_{REF(x2)}$ ) are provided that are suitable for output to the user.

An onboard dc-to-dc converter generates two regulated “high” (greater than the supply) voltages referred to as  $V_{BOOST(H)}$  and  $V_{BOOST(L)}$ . These voltages supply critical functions with maximum immunity from supply variations.

## SERIAL INTERFACE

The serial interface is used to alter the control state of the device from an external microcontroller or other digital CMOS source. In addition to the various operational and diagnostic control states (modes), all critical constants, variables, and parameters can be adjusted through this interface. The serial interface is a synchronous serial three-wire port with serial data input, clock, and load (active low) functions. When LOAD is high, the serial interface is disabled and the chip is not affected by changes in SER DATA IN or CLK SER. To write data to the serial interface, CLK SER should be low prior to LOAD going low. Once LOAD goes low, information at SER DATA IN is read into the shift register on the positive-going transitions of CLK SER.

## TERMINAL FUNCTIONS

<b>ANALOG SUPPLY</b>	$V_{CC(A)}$ ; supplies all analog functions except for gate drive of power output transistors. For most applications, $V_{CC(A)}$ , $V_{CC(D)}$ , and $V_{CC(PWR)}$ are connected together.
<b>DIGITAL SUPPLY</b>	$V_{CC(D)}$ ; supplies all digital functions. For most applications, $V_{CC(A)}$ , $V_{CC(D)}$ , and $V_{CC(PWR)}$ are connected together.
<b>LOAD SUPPLY</b>	$V_{CC(PWR)}$ ; supplies all voice-coil and spindle power output transistors. This terminal is internally connected to the source of the blocking FET used to isolate $V_M$ from $V_{CC(PWR)}$ on system failure or shutdown. For most applications, $V_{CC(A)}$ , $V_{CC(D)}$ , and $V_{CC(PWR)}$ are connected together.
<b>SUB</b>	Substrate. This terminal must be connected to ground.
<b><math>V_M</math></b>	Supplies power to the voice-coil and spindle power output transistors. Connect this terminal to the external flyback inductor for the dc-to-dc converter; internally connected to the drain of the blocking FET.
<b><math>L_{FLYBCK}</math></b>	External inductor for the dc-to-dc converter.
<b><math>V_{BOOST(H)}</math></b>	Internally generated “high” voltage for driving the gates of all source-side power output transistors. This source is regulated and requires a compensation capacitor from this terminal to ground.



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<b>V<sub>BOOST(L)</sub></b>	Internally generated intermediate voltage for driving the gates of all sink-side power output transistors, the bandgap reference, and fault monitors. This source is regulated and requires a compensation capacitor from this terminal to ground.
<b>V<sub>PF(GATE)</sub></b>	Control voltage provided to drive the gate of an optional external enhancement-mode power FET, augmenting the internal blocking FET between V <sub>CC(PWR)</sub> and V <sub>M</sub> .
<b>V<sub>REF</sub></b>	Programmable reference voltage output. This reference tracks V <sub>REF(x2)</sub> and may be used as a relative signal ground.
<b>V<sub>REF(x2)</sub></b>	Programmable reference voltage output. Derived from a trimmed internal bandgap reference. May be used as the reference for system DAC and ADC.
<b>POR<sub>OUT</sub></b>	Power-on reset for the application system. Active low guaranteed by design to be active on power up. Also occurs as a result of V <sub>CC(A)</sub> degrading below the BLACKOUT under-voltage threshold.
<b>TRIP ADJ</b>	V <sub>UV (TRIP)</sub> ; trip threshold adjust input (an external resistor divider between V <sub>CC(A)</sub> and ground) for the under-voltage BLACKOUT fault monitor. A capacitor at this terminal can provide for time domain filtering.
<b>CLK</b>	f <sub>CLK(2MHz)</sub> ; reference for all internal analog signal-processing functions. Affects frequency domain placement of all poles, zeros, and bandwidths.
<b>SER DATA IN</b>	Non-inverting microcontroller serial-data input used for transferring data to all internal parameter and mode-control registers.
<b>CLK SER</b>	f <sub>CLK(SER)</sub> ; reference for the serial data interface. Data is transferred on the positive-going edge of this clock.
<b>LOAD</b>	Active low. Begins and ends data transfer.
<b>EXT XFR</b>	Direct clock gating data from temporary internal latch to control register. This continuous time input is redundant to the XFR bit, which is embedded in the serial data format. It is internally synchronized to the f <sub>CLK(2MHz)</sub> positive-going edge.
<b>AMUX<sub>1</sub></b>	Analog input or output. Also used to drive internal nodes.
<b>AMUX<sub>2</sub></b>	Analog input or output. Also used to drive internal nodes for calibration and measurement on internal analog functions.
<b>DMUX<sub>OUT</sub></b>	Non-inverting digital multiplexer output. Used to probe internal nodes allowing precise time-domain measurements. Also used to extract internal status and diagnostic information.
<b>OUT<sub>P</sub></b>	V <sub>OUT(P)</sub> ; voice-coil power output. Full-bridge differential complement to V <sub>OUT(N)</sub> .
<b>OUT<sub>N</sub></b>	V <sub>OUT(N)</sub> ; voice-coil power output. Full-bridge differential complement to V <sub>OUT(P)</sub> .
<b>V<sub>SENS(act)</sub></b>	The voltage at this terminal is proportional to voice-coil actuator current.

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<b>R<sub>gm(act)</sub></b>	A resistor between this terminal and V <sub>SENS(act)</sub> is used to adjust the forward transconductance gain of the voice-coil transconductance amplifier.
<b>RETRACT</b>	Active high retract input from the system. Continuous-time direct input to cause immediate retract mode.
<b>EXT ACT</b>	V <sub>SERVO</sub> ; summing junction at the input of the voice-coil transconductance amplifier. This direct continuous-time input to the actuator g <sub>m</sub> amplifier provides diagnostic as well as feed-forward access.
<b>OP<sub>1(IN)</sub></b>	Operational amplifier inverting input. The non-inverting input is internally connected to V <sub>REF</sub> .
<b>OP<sub>1(OUT)</sub></b>	Operational amplifier output. This undedicated operational amplifier functions in continuous time.
<b>VEL<sub>INN</sub></b>	Inverting input of operational amplifier portion of over-velocity fault circuit.
<b>VEL<sub>INP</sub></b>	Non-inverting input of operational amplifier portion of over-velocity fault circuit.
<b>VEL</b>	V <sub>VEL</sub> ; output of the over-velocity operational amplifier. Also internally connected to the inputs of two comparators that provide the positive and negative velocity fault thresholds.
<b>OUT<sub>A</sub></b>	V <sub>OUT(A)</sub> ; spindle motor power output terminal.
<b>OUT<sub>B</sub></b>	V <sub>OUT(B)</sub> ; spindle motor power output terminal.
<b>OUT<sub>C</sub></b>	V <sub>OUT(C)</sub> ; spindle motor power output terminal.
<b>C TAP</b>	Connection to spindle motor center tap; provides the differential reference for detection of back-EMF zero crossings. If this terminal is not connected, the device will internally simulate the centertap of the motor.
<b>V<sub>SENS(spin)</sub></b>	The voltage at this terminal is proportional to the spindle motor current.
<b>R<sub>gm(spin)</sub></b>	A resistor connected from this terminal to V <sub>SENS(spin)</sub> provides for adjusting the forward transconductance gain of the spindle transconductance amplifier.
<b>f<sub>com</sub></b>	A digital logic output that goes low to high on a back-EMF zero crossing; provides tach-like information to the spin controller.
<b>EXT COM</b>	f <sub>sync</sub> ; hard external commutation sequence start (positive-edge triggered). May be used to place spindle commutation edges in the inter-sector gap, or for phase-locking multiple spindle drivers.
<b>EXT SPIN mand</b>	V <sub>spin</sub> ; direct continuous time input to the spindle transconductance amplifier/driver. Zero de-current occurs at 2.00 V; full-scale positive demand current occurs at 4.00 V.
<b>SW<sub>IN</sub></b>	Input for uncommitted analog switch.
<b>SW<sub>OUT</sub></b>	Output of uncommitted analog switch.
<b>SW<sub>ON</sub></b>	Logic input for uncommitted analog switch; a high level connects SW <sub>IN</sub> to SW <sub>OUT</sub> .

**8980***SUPER*SERVO™*SPINDLE & VOICE-COIL**ACTUATION MANAGER/DRIVER***ADDRESS MAP AND DATA BIT ASSIGNMENTS**

Address Word	Data Bit	Function
00H	0 – 3	Blanking Time
	4 – 7	Commutation Delay Time
01H	0 – 5	Coast Time
	6	Commutation Multiplexer
	7	Not used at this time
02H	0 – 3	Startup Time
	4 – 7	Watchdog Time
03H	0 – 7	Spindle-Demand DAC Current Magnitude
	8	Reverse Commutation Mode
04H	0 – 3	Spindle Slew Rate Control
	4 – 6	Spindle Multiplexer
	7	Not used at this time
05H	0 – 3	Spindle Transconductance Amp. Bandwidth
	4 – 6	Spindle Transconductance Amp. Local Zero
06H	0 – 3	Internal 6.25 kHz Oscillator Frequency Trim
	4 – 7	Not used at this time
07H	0 – 7	Not used at this time
08H	0 – 11	Servo-Demand DAC Current Magnitude
09H	0 – 7	Not used at this time
0AH	0 – 3	Low-Pass Filter Damping (Zeta) Control
	4	Not used at this time
	5	Low-Pass Filter Reset Control
	6 – 7	Not used at this time
0BH	0 – 3	Notch Depth ( $\alpha_3$ ) Control
	4 – 7	Not used at this time

Address Word	Data Bit	Function
0CH	0 – 3	Notch Width (Zeta $D_{z3}$ ) Control
	4	Notch Reset Control
	5 – 7	Not used at this time
0DH	0 – 4	Low-Pass Filter Freq. Synth. ( $D_{n2}$ ) Control
	5 – 7	Not used at this time
0EH	0 – 4	Notch Center Frequency ( $D_{n3}$ ) Control
	5 – 7	Not used at this time
0FH	0 – 3	Actuator Bandwidth ( $BW_{ACT}$ ) Control
	4 – 6	Actuator Zero (Damping) Control
	7	Not used at this time
10H	0 – 2	Retract Velocity Demand Voltage
	3 – 5	Actuator Analog Multiplexer Input Select
	6 – 7	Not used at this time
11H	0 – 7	Sleep Mode Manager
12H	0 – 3	Fault Control Monitor
	4 – 6	Programmable References Voltage Select
	7	Long Spindle Braking Delay
13H	0 – 2	Analog Multiplexer-2 Selection
	3 – 5	Digital Multiplexer Output Selection
	6 – 7	Not used at this time
14H	0 – 2	Analog Multiplexer-1 Selection
	3	Chopper Stabilization of LP & Notch Filters
	4	Disable actuator retract during fault
	5 – 7	Not used at this time
15H	0 – 2	Actuator Power Voltage Amplifier Deadband Trim

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