SSI 32M591
Three-Phase 5-1/4 Inch Winchester Motor Speed Control

July, 1990

DESCRIPTION

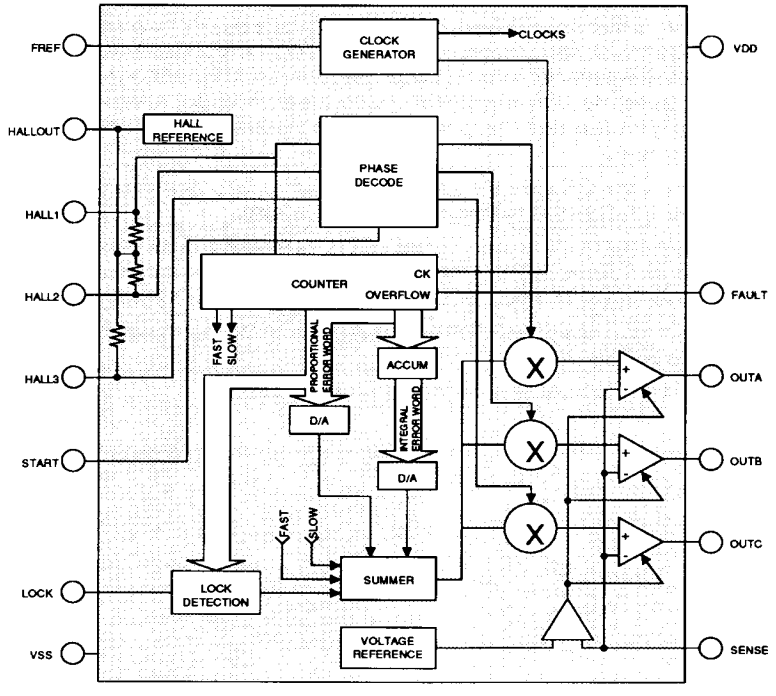
The SSI 32M591 is a motor controller IC designed to provide all timing and control functions necessary to start, drive and brake a three-phase brushless DC spindle motor. The IC requires three external power transistors (such as Darlington power transistors), one external power resistor, and an external frequency reference. The three motor HALL sensors are directly driven and decoded by the device. The controller is optimized for a 3600 rpm disk drive motor using a 2 MHz clock. Motor protection features include stuck rotor shutdown, supply and clock fault detection, all of which are indicated by a FAULT signal, and coil over-current detection and control. A LOCK signal is provided to indicate that the motor is at speed. The device's linear control loop controls the power drivers using Pulse Amplitude Modulation.

FEATURES

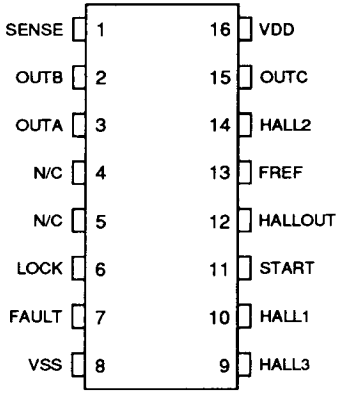
- **CMOS with TTL/LSTTL compatible control functions**
- **Single +12 volt power supply**
- **All motor START, DRIVE, and STOP timing and control**
- **Includes HALL-Effect sensor drive and input pins**
- **Highly accurate speed regulation of ±0.05 %**
- **On-chip digital filtering requires no external compensation of adjustments**
- **Provides protection against stuck rotor, motor coil over-current, supply fault, or clock fault**
- **At speed indication provided**

6

BLOCK DIAGRAM



PIN DIAGRAM



CAUTION: Use handling procedures necessary for a static sensitive component.

Powered by ICminer.com Electronic-Library Service CopyRight 2003

CIRCUIT OPERATIONS

The device incorporates both analog and digital circuit techniques to utilize the advantages of each. The analog portion of the loop uses switched capacitor filter technology to eliminate external components. The control loop uses a Pulse Amplitude Modulation (PAM) control scheme to avoid the switching transients and torque ripple inherent in Pulse Width Modulation (PWM) schemes.

PIN DESCRIPTION

SYMBOL	I/O	DESCRIPTION
VDD	I	+12V Power supply
VSS	I	Ground
FREF	I	FREQUENCY REFERENCE INPUT: A TTL compatible input used by the device to set and maintain the desired motor speed and operate circuit blocks. This input level must not exceed VDD at any time.
HALLOUT	O	HALL SENSOR BIAS OUTPUT: Provides a regulated bias voltage for the Hall effect sensors, inside the motor.
HALL1, HALL2, HALL3	I	HALL SENSOR INPUTS: The TTL open-collector type outputs of the motor's Hall switches feed these inputs which have a resistor pullup to the HALLOUT bias voltage. The HALL1 input is used to index the control loop counter. Refer to figure 1 for input timing.
OUTA, OUTB, OUTC	O	DRIVER OUTPUTS: These three driver outputs drive the external power transistors, such as TIP120 NPN Darlington power transistors shown in the typical application. The power transistors control the motor current through the current setting resistor Re. The motor current is V(sense)/Re. During normal operation, the driver output voltages are adjusted as necessary to maintain the proper motor speed and drive current. Refer to figure 1 for output timing.
SENSE	I	COIL CURRENT SENSE INPUT: Senses the coil current and limits the sense voltage to the threshold by limiting the drive to the external power transistors.
LOCK	O	AT SPEED INDICATOR OUTPUT: An open drain LSTTL compatible output that indicates with an active low that the period of the motor is within the controller's linear range. Because of the accuracy of the loop, the LOCK pin is a good "at speed" indicator.
FAULT	O	FAULT INDICATOR OUTPUT: Goes high when the motor is determined to be stalled, VDD is low, or FREF clock is too slow.
N/C	-	NO CONNECTION: These pins must be left unconnected and floating.
START	I	

Powered by ICminer.com Electronic-Library Service CopyRight 2003

FUNCTIONAL DESCRIPTIONS

A binary counter is preset once per motor revolution by an index signal developed from the HALL1 input. On the next index pulse, the remaining least significant bits are loaded into the proportional D/A and accumulated by a saturating accumulator. The most significant bits are loaded into the integral D/A. The size of the accumulator and the bit locations determine the major scaling (within a factor of two) for the gain and zero location of the filter. To prevent overflow in the proportional D/A , the counter is decoded to detect overflow and the proportional D/A is saturated as needed. The overflow also generates a boost signal used in the summer. The range of the accumulator is larger than the linear range of the proportional channel to help filter small load disturbances that tend to saturate the proportional channel. The entire counter is also used to provide a time-out feature to protect the motor and external circuitry.

PROTECTION FEATURES

Low Voltage Detection
If the supply drops below the detect threshold, the device will turn off all of the external power transistors to prevent damage to the motor and the power devices. The FAULT pin goes high in this condition.

Stalled Rotor Shutdown
If the delay from power onset to a positive index transition or the time interval between successive index transitions is greater than the prescribed time, the device interprets this delay as a stalled rotor and reduces the motor current to zero until such time as one positive index transition is detected or until power is removed and reapplied. The FAULT output goes high when the motor is determined to be stalled.

Motor Coil Over-Current
Refer to SENSE input description. The voltage generated by motor coil current through Re is sensed as shown in the typical application. The sense input threshold limits the maximum coil current.

FREF Clock Fault
If the FREF frequency drops below the specified minimum frequency, the driver will shut down and the FAULT pin will go high.

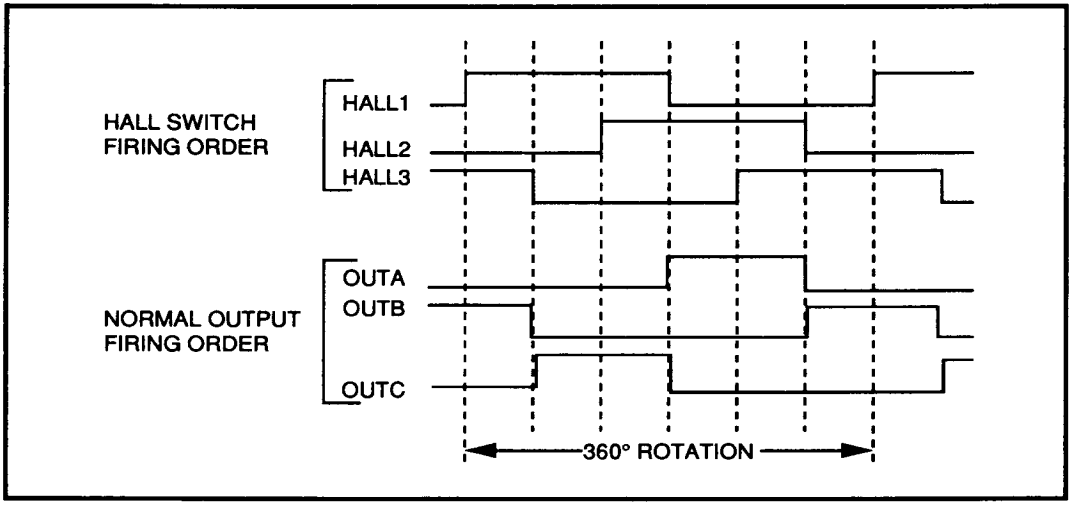


FIGURE 1: HALL Switch/Driver Timing Relationship

Powered by ICminer.com Electronic-Library Service CopyRight 2003

ELECTRICAL CHARACTERSTICS

ABSOLUTE MAXIMUM RATINGS

Maximum limits indicate where permanent device damage occurs. Continuous operation at these limits is not intended and should be limited to those conditions specified in the DC operating characteristics.

PARAMETER	RATING	UNIT
Positive Supply Voltage, VDD	14	V
Storage Temperature	-65 to + 125	°C
Pin Voltage (except FAULT and LOCK)	-0.3 to VDD +0.3	V
FAULT and LOCK Pin Voltage	-0.3 to VDD +5.0	V
HALLOUT Current	20	mA
Lead Temperature (soldering, 10 sec.)	260	°C

RECOMMENDED OPERATION CONDITIONS

PARAMETER	CONDITIONS	MIN	NOM	MAX	UNITS
DC Supply Voltage, VDD		10.8	12.0	13.2	V
Input Clock, FREF		1.9998	2	2.0002	MHz
Ambient Temperature, Ta		0		70	°C
Emitter Resistor, Re		0.392	0.4	0.408	Ω
Power Darlington Vbe		0.8		1.8	V
Motor Parameters (1)	$\frac{\text{Motor Frequency}(s)}{\text{Motor Current}(s)} = \frac{KT}{Js + KD}$				
KT, Torque Constant Range	(0.15 Nt-m/A nom)	-10		+10	%
J, Inertia Range	(489×10^{-6} Nt-m-sec^2 nom)	-33		+33	%
KD, Damping Factor Range	(31.8×10^{-6} Nt-m/rad/s nom)	-33		+33	%
Winding resistance (2)			2.0		Ω
Winding inductance			2.0		mH
Back EMF (2)			0.0159		rad/s V

Notes:

(1) The motor parameters given are for a typical motor. The device will work for a range of motors near this nominal motor.

(2) The motor must have a back EMF less than 10 volts peak (measured from center tap to drive transistor collector/drain) at speed to insure linear operation of drive transistors and a coil resistance small enough to insure adequate start current.

Powered by ICminer.com Electronic-Library Service CopyRight 2003

DC ELECTRICAL CHARACTERISTICS.
Unless otherwise specified, 10.8V ≤ VDD ≤ 13.2V: 0°C ≤ Ta ≤ 70°C; FREF = 2.000 MHz; Re = 0.4Ω; Motor Configuration is 4-pole 3-phase center-tap "Y."

PARAMETER	CONDITIONS	MIN	NOM	MAX	UNITS
Power Supply Current					
ICC	Clock Active 1(HALLOUT) = 15 mA 1 Driver loaded to = 5 mA 2 Drivers unloaded			30	mA
Power Dissipation				400	mW
Fault Detection					
Low Voltage Detect Threshold		6.8		9.0	V
Input Logic Signals - 'FREF' and 'START' Inputs					
Vil, Input Low Voltage				0.08	V
Iil, Input Low Current	Vin = 0	–500			µA
Vih, Input High Voltage		2.0			V
IiH, Input High Current	Vin = 5			100	µA
Output Logic Signals - 'LOCK' and 'FAULT' Pins					
Vol	Isink = 2mA			0.4	V
Ioh	Vout = VDD			10	µA
HALL Sensor Interface					
HALLOUT Bias Voltage	I = 0 to –15 mA	5.0		6.8	V
HALL1,2,3 Pullup Resistance	To HALLOUT pin	5		20	kΩ
Input Low Voltage				1.0	V
Input High Voltage		4.0			V
Driver Outputs					
Sink Capability	Vol = 0.5V	1.0			mA
Source Capability	Voh = 3.0V	–5.0			mA
Capacitive Load Drive Capability			50.0		pF
Sense Input And Over-Current Control					
Threshold Voltage		0.9		1.1	V
Input Current		–100		100	µA

Powered by ICminer.com Electronic-Library Service CopyRight 2003

AC ELECTRICAL CHARACTERISTICS

Unless otherwise specified, 10.8V ≤ VDD ≤ 13.2V; 0°C ≤ Ta ≤ 70°C; FREF = 2.000 MHz; Re=0.4Ω.

PARAMETER	CONDITIONS	MIN	NOM	MAX	UNITS
Fault Detection					
Stalled Rotor Shutdown Time	Power On to driver	0.850		0.900	sec
Low FREF Shutdown Threshold				100	Hz
Lock Indication					
Lock Range	Motor Speed	3585		3615	Hz
Control Loop Parameters*					
Divider Ratio	FREF/Fmotor		33,336		
Instantaneous Speed Error	Referenced to 60Hz	–0.035	0.01	0.015	%
Index to Index Jitter (16/FREF)	Total jitter			8	µs
Loop Bandwidth	Nominal motor Re = 0.40Ω		2		Hz
Loop Zero	Ki/Kp		1.0		Hz
Maximum Running Current	Re = 0.40Ω	1.50			Amps
Minimum Running Current	Re = 0.40Ω			0	Amps
Start Current	Re = 0.40Ω	2.25		2.75	Amps
Input Logic Signals-'FREF' and 'START' Pins					
Input Capacitance				25	pF
Hall Sensor Interface					
Input Capacitance				25	pF
Sense Input and Over-current Control					
Input Capacitance				25	pF

*Control Loop Notes:

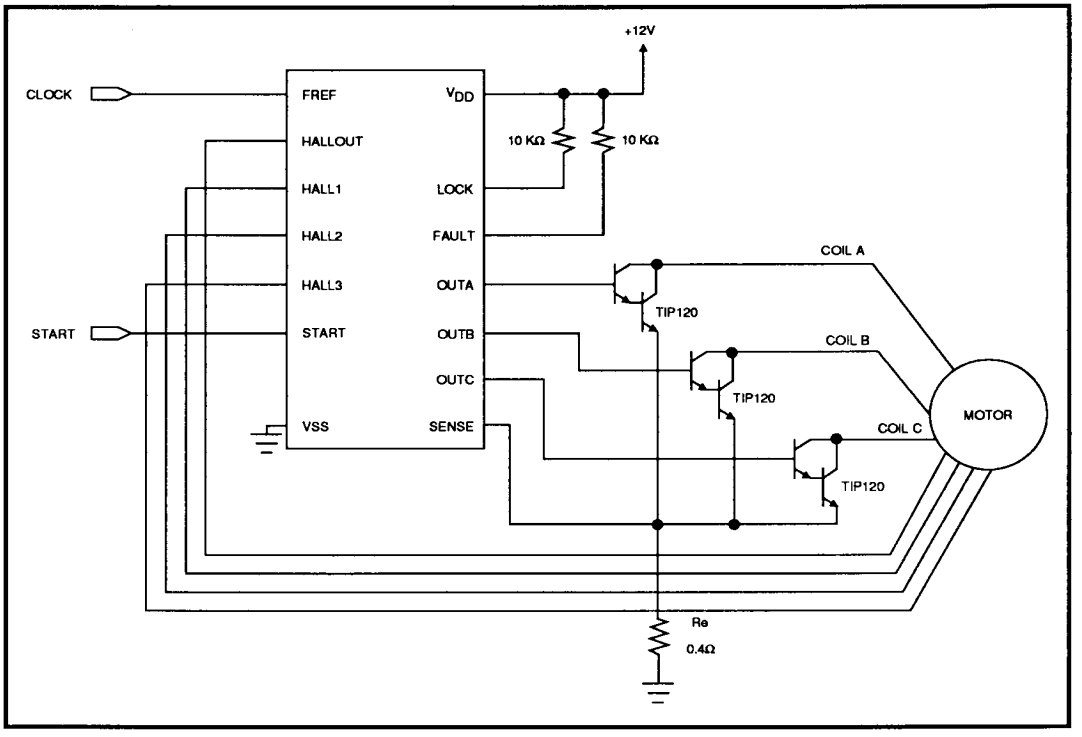
Running current limits refer to capabilities during speed correction.

The motor control loop consists of counters, logic, and digital-to-analog converters that provide loop time constants. The continuous time transfer function of the on chip control can be modeled as follows:

$$H(s) = \frac{Vc(s)}{Fm(s)} = \frac{Ki}{s} + Kp$$

Vc(s) is the voltage applied to the external setting resistor Re by the modulator. By adjusting the value of Re the gain the motor sees can be adjusted, as can the starting current.

Powered by ICminer.com Electronic-Library Service CopyRight 2003



Typical Application Diagram

6

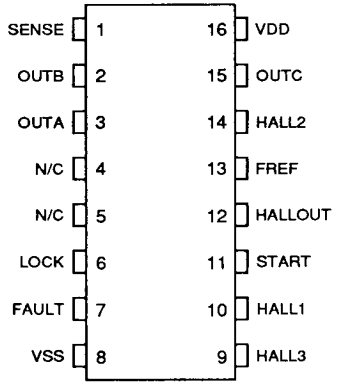
Powered by ICminer.com Electronic-Library Service CopyRight 2003

SSI 32M591
Three-Phase 5-1/4 Inch
Winchester Motor Speed Control

PIN DIAGRAM
(TOP VIEW)

THERMAL CHARACTERISTICS: Øja

16-Pin DIP	75°C/W
16-Pin SOL	105°C/W



16-Pin DIP

ORDERING INFORMATION

PART DESCRIPTION	ORDER NO.	PKG. MARK
SSI 32M591 16-Pin Plastic DIP	SSI 32M591-CP	32M591-CP
SSI 32M591 16-Pin SOL	SSI 32M591-CL	32M591-CL

No responsibility is assumed by Silicon Systems for use of this product nor for any infringements of patents and trademarks or other rights of third parties resulting from its use. No license is granted under any patents, patent rights or trademarks of Silicon Systems. Silicon Systems reserves the right to make changes in specifications at any time without notice. Accordingly, the reader is cautioned to verify that the data sheet is current before placing orders

Silicon Systems, Inc., 14351 Myford Road, Tustin, CA 92680 (714) 731-7110, FAX (714) 731-5457

©1989 Silicon Systems, Inc.

Powered by ICminer.com Electronic-Library Service CopyRight 2003