SGS-THOMSON MICROELECTRONICS

GS-D200M

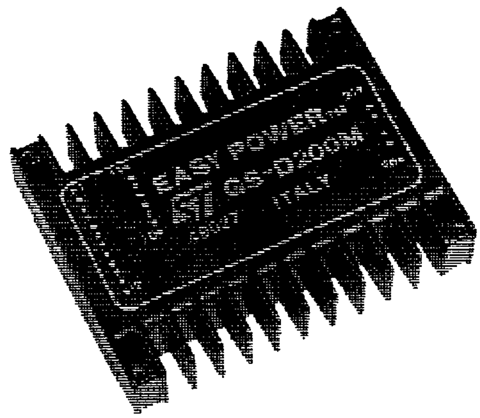
2.5A MICROSTEP DRIVE MODULE FOR STEPPER MOTORS

FEATURES

- Wide supply voltage range (12 to 40V)
- High peak phase current (2.5Apk)
- 1/128 phase current resolution
- Logic signals TTL/CMOS compatible
- Direct interface to microprocessors
- Chopping regulation of the phase current
- Programmable peak motor phase current
- Remote inhibit/enable
- Thermal protection

DESCRIPTION

The GS-D200M is a module specifically designed to drive bipolar stepper motors in the microstep mode.
The unit interfaces the microprocessor as a parallel port and two phase, bipolar, permanent magnet stepper motor.
The phase current (up to 2.5Apk) is controlled in a chopping mode by using a mixed recirculation method that allows the best overall system performance.
The microstep per step rate is determined by the microprocessors software according to the application requirement: the maximum resolution of the phase current is 1/128 of the peak value.
The two phases of the motor are driven by two internal and separate H-bridges made of powerfets to minimize the commutation and conduction losses.



ABSOLUTE MAXIMUM RATINGS

Symbol	Parameter	Value	Unit
V_S	DC Supply Voltage	42	V
V_{SS}	DC Logic Supply Voltage	7	V
T_{stg}	Storage Temperature Range	– 40 to +105	°C
T_{cop}	Operating Case Temperature Range	– 20 to +85	°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C and V_S=24V unless otherwise specified)

Symbol	Parameter	Test Conditions	Value			Unit
			Min	Typ	Max	
V_S	DC Supply Voltage		12		40	V
V_{SS}	DC Logic Supply Voltage		4.75	5	5.25	V
I_S	Quiescent Supply Current			20		mA
I_{SS}	Quiescent Logic Supply Current	V_{SS} = 5V		60		mA
I_{ph}	Phase Peak Current				2.5	A
V_{dr}	Voltage Drop	I_{ph} = 2A			2.5	V
V_i	Logic Input Voltage	Low High	 2		0.8 V_{SS}	V
V_o	Logic Output Voltage	Low High	 2		0.8 V_{SS}	V
t_{off}	Recirculation Time			32		µs
Ds	Select and Data to Strobe Set Up Time		100			ns
Dh	Select and Data to Strobe Hold Time		600			ns
Stpw	Strobe Pulse Width		700			ns
Csrt	Data Uptdating Frequency				400	kHz
Rth	Case to Ambient Thermal Resistance			5		°C/W

Figure 1. Signals Timing

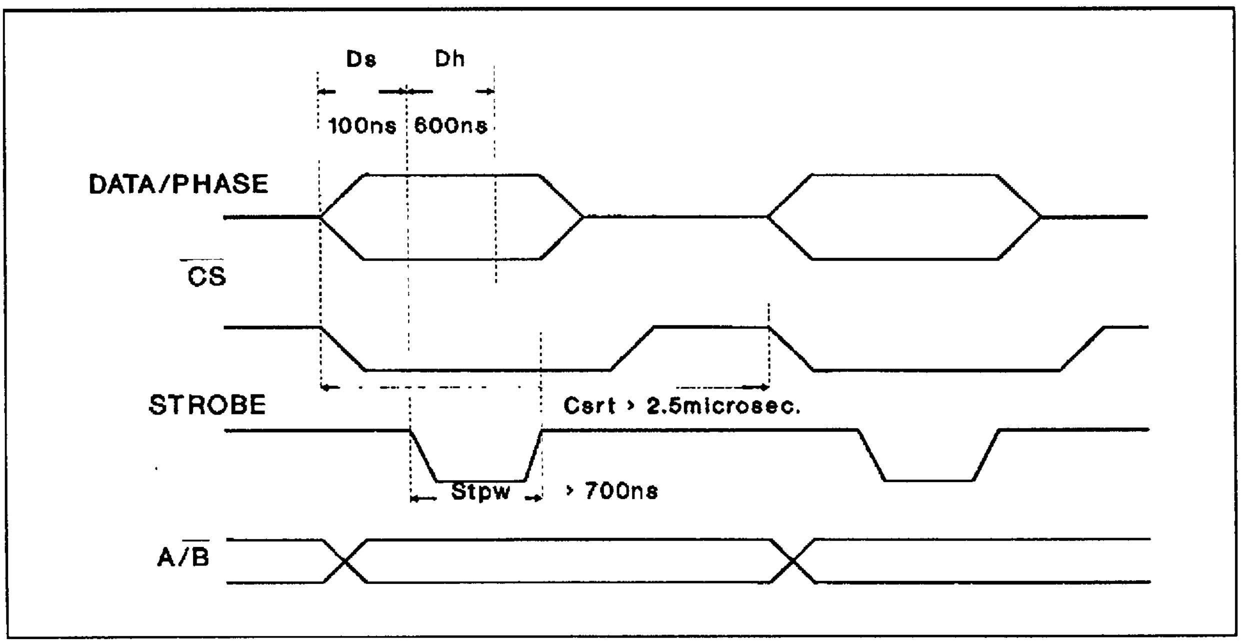


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Figure 2. GS-D200M Equivalent Block Diagram

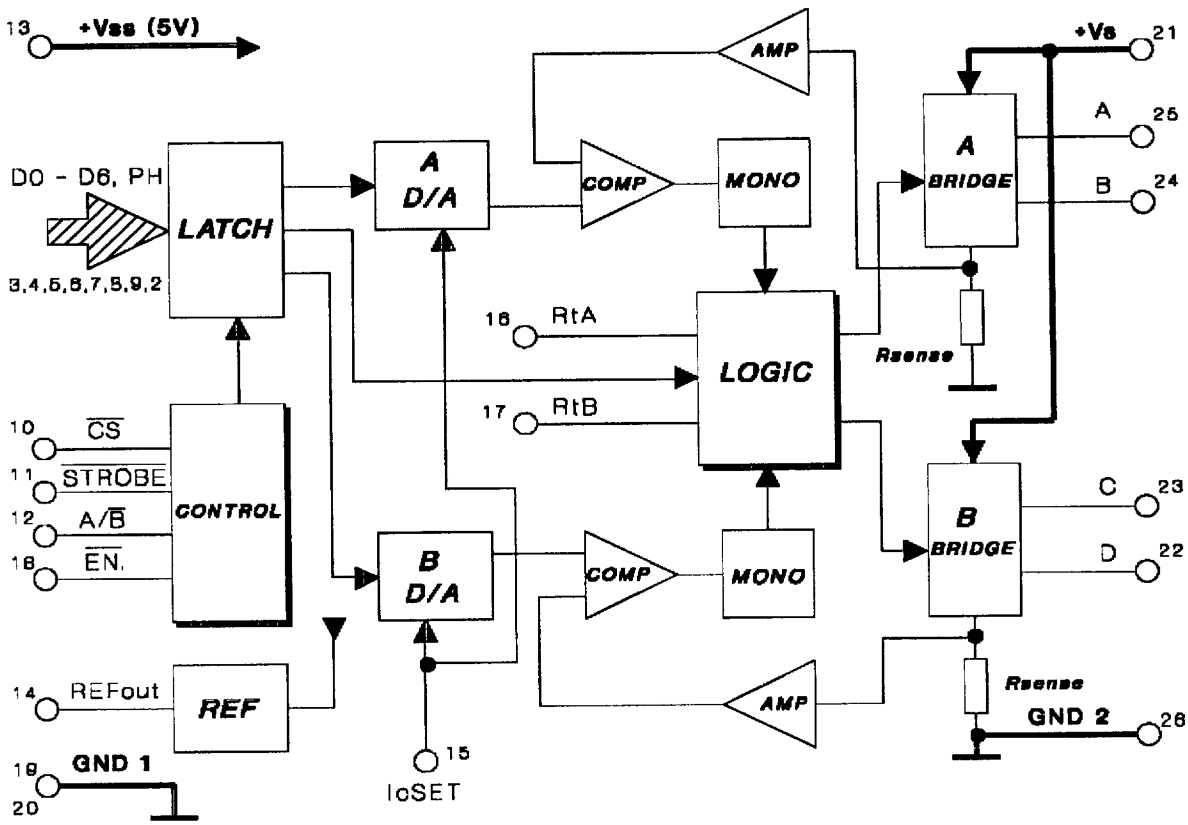

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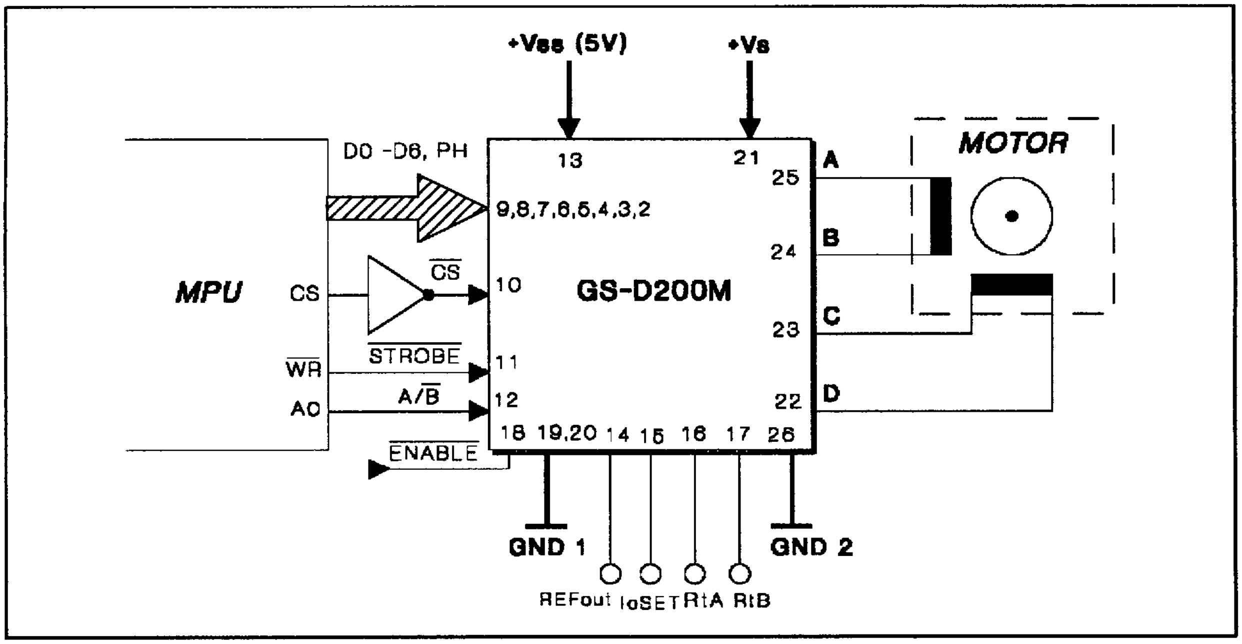
Figure 3. Interfacing the GS-D200M to a Microprocessor and to Stepper Motor.



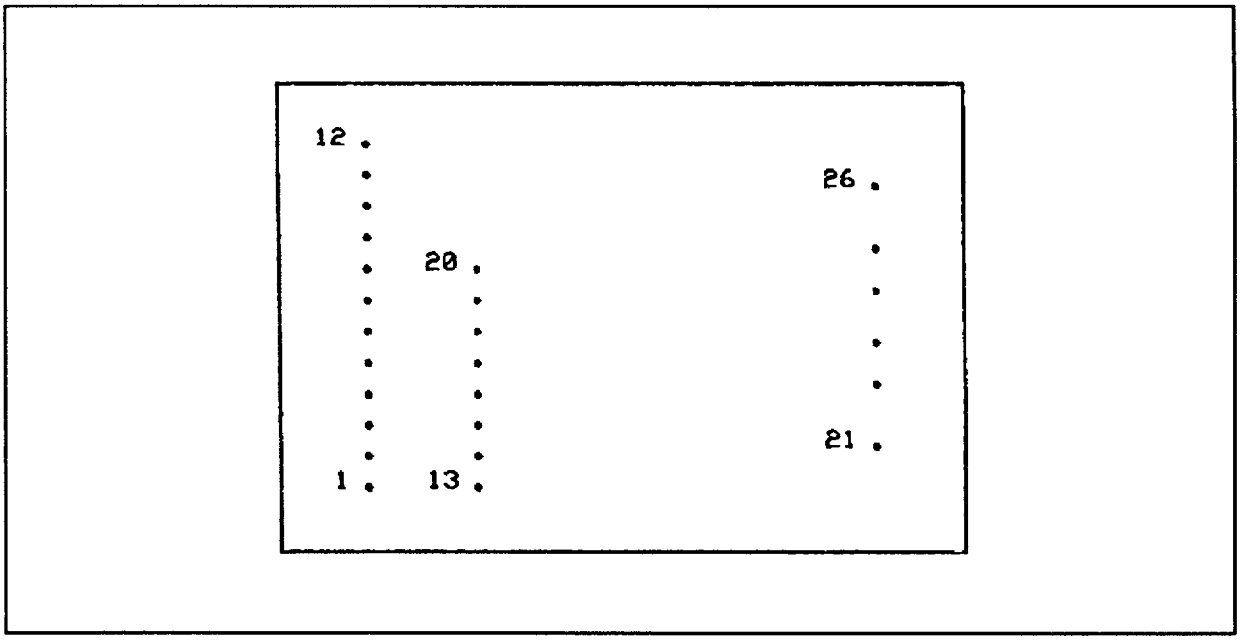
PIN DESCRIPTION

Pin	Function	Description
1	V_{ss}	5V supply input. Maximum voltage must not exceed 7V.
2	Phase	Phase logic information. This input, normally connected to bit7 of the data bus, determines the direction of conduction for the addressed power driver.
3	D_6	Data inputs. The value present on these inputs is stored into the addressed DAC latch during the high-to-low transition of the STROBE input.
4	D_5	
5	D_4	
6	D_3	
7	D_2	
8	D_1	
9	D_0	
10	CS	Chip select input. Data can be stored into DAC latches only when CS is low.
11	STROBE	Latches strobe command. The data present on the bus is transferred to the addressed DAC latch on the high-to-low transition of this input.
12	A/B	DAC latch selection input. When high the A DAC is addressed.
13	V_{ss}	5V supply input. Maximum voltage must not exceed 7V.
14	REF_{out}	Reference output. A 2.5V reference voltage is available on this pin for phase current setting.
15	Ioset	Current setting input. A resistor connected between pin 14 and this pin sets the phase current peak value.
16	R_{tA}	Phase A ripple current setting resistor.

PIN DESCRIPTION (Cont'd)

17	RtB	Phase B ripple current setting resistor.
18	DISABLE	Power driver disable logic input. When high or unconnected causes the output power stages to float.
19	GND	Return path for the logic.
20	GND	Return path for the logic.
21	V_S	Module and motor supply voltage. Maximum voltage must not exceed 40V.
22	D	D output. A motor winding is connected between D and C outputs.
23	C	C output. A motor winding is connected between C and D outputs.
24	B	B output. A motor winding is connected between B and A outputs.
25	A	A output. A motor winding is connected between A and B outputs.
26	GND1	Ground path for the motor current.

Figure 4. Connection Diagram (Bottom view)



MICROSTEPPING BASICS

Stepping motors have the advantage to be usable in an open-loop system's architecture that controls speed and positioning.
However, they exibit also two major limitations on achievable resolution and mechanical resonance.
The microstepping mode of operation can pratically eliminate these two limitations.

Resolution Improvement Through Microstepping

Basically, microstepping is achieving finer electrical resolution than is offered by conventional full-step and half-step driving.
A typical and simplified two-phase-on (normal mode) drive of a stepping motor is shown in fig. 5.

Figure 5. Two-Phase-on (Normal mode) Drive.

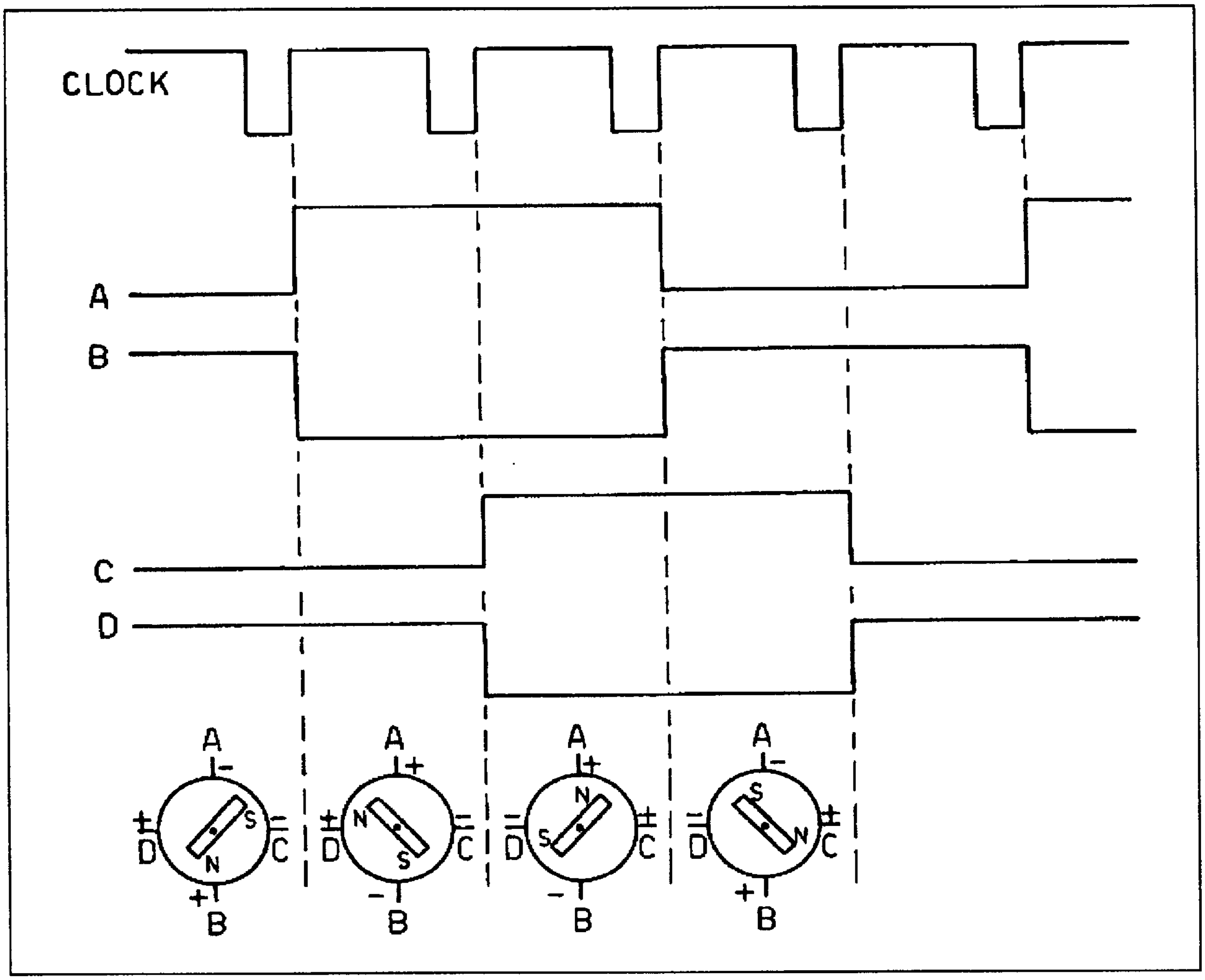


Figure 6. Phase Current for Four Full Step.

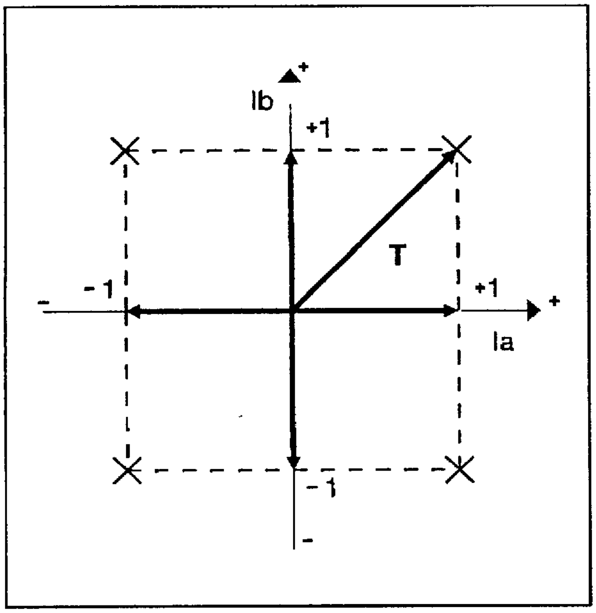
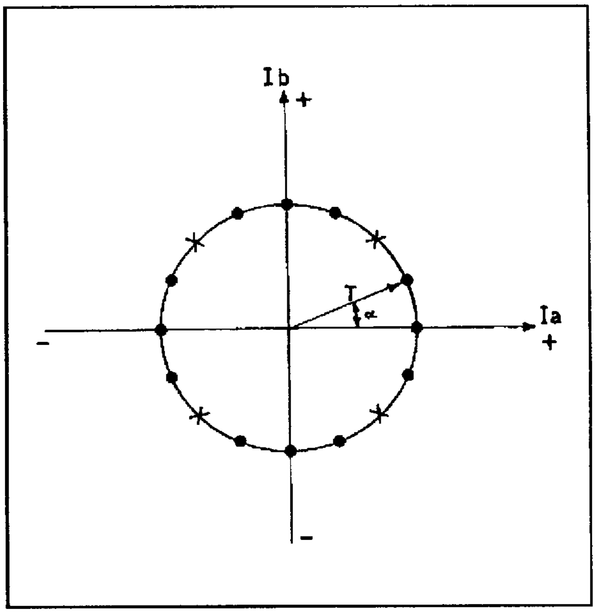


Figure 7. Microstepping



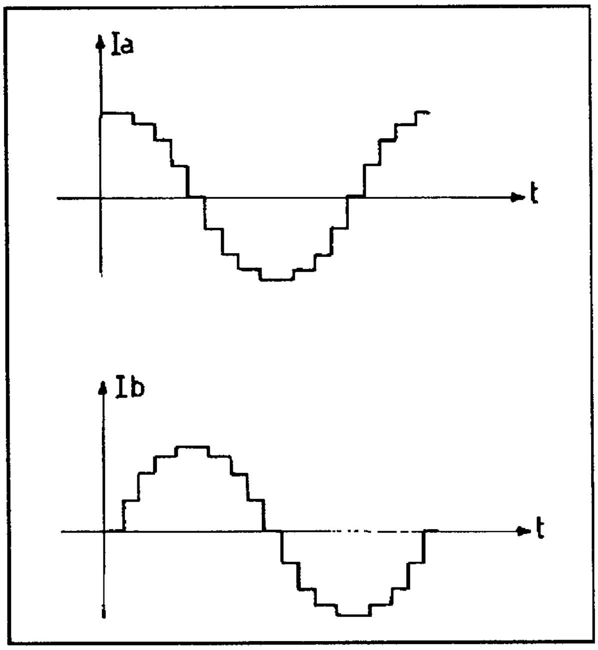
A full cycle (360 electrical degrees) of the driving signals generate exactly four full steps (one torque cycle).
One full step is, therefore, equivalent to 90° of electrical signal.
This is equivalent to have two windings with current I_a and I_b mechanically placed at 90° along x, y, axis as shown in fig. 6. The two currents have discrete values: 0, +1, −1.

The torque T is proportional to the current in the motor winding and the resultant torque is the vector sum of the individual torques produced by phase a and phase b current. The motion direction is determined by the direction of the current flow.
From fig. 6, it is evident that to reduce the mechanical step angle, the torque vector should have more than the 4 position indicated by the crosses.
The ideal situation would be for the resultant torque vector to fall in a unit circle for all positions as shown in fig. 7.

This would occur if the winding current rather than square waves as shown in fig. 5 are orthogonal functions, such as sine and cosine.

In fig. 7 four microsteps/step are shown. The correspondent phase currents are shown in fig. 8.

Figure 8. Phase Current Profile for 4 microsteps/step



Substantially, the microstepping mode is obtained by subdividing each full step into a fixed number of microsteps; this, in turns, is obtained by driving the motor winding with intermediate current levels.

The higher the number of intermediate levels, the closer the torque vector will follow the unity circle of fig. 7. However, the mechanical characteristics of the motor in response to these intermediate levels will make useless a very high number of levels: in the GS-D200M, the maximum number of microsteps/step is fixed at 128.
Real motors have multiple poles pairs to reduce the step angle to a few mechanical degrees for a full step.
Most steppers have resolution of 200 steps/revolution i.e. 1.8° per full step.
The finer electrical resolution obtained by 128 microsteps/step is more than adequate for practical application.

Mechanical Resonance Improvement

Microstepping can help smooth out the mechanical motion of a stepper motor.
Large pulse drive waveforms encountered in full step mode create mechanical forces that may translate into mechanical resonances in a positioning system.

These resonances are also depending on load characteristics and they are difficult to control because of low damping capability of stepper motors.
Resonance may cause loss of synchronization i.e. the motor can skip or gain a step.
Microstepping reduces large current transients and it is beneficial in reducing or eliminating the resonance problem.

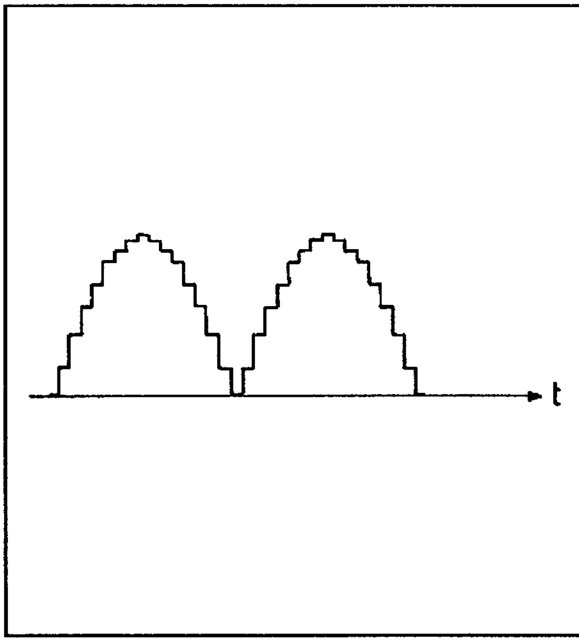
GS-D200M DESCRIPTION

The block diagram of the module is shown in fig. 2.
The GS-D200M implements all the functions needed to achieve intelligent power drive of a stepper motor in a microstep mode.

The two functions, sine and cosine, are digitized, stored in a look-up-table of the external microprocessor and supplied to the module.
The magnitude only of the two signals is sufficient since the software can take into account the sign i.e. the direction.
The typical waveform has the form of a rectified sine wave as shown in fig. 9.

The current waveform can also be modified, via software, to take into account motor resonance and damping.

Figure 9. Digitized, Rectified Sine Wave



The GS-D200M includes two data latches that can be easily interfaced to a microprocessor, either to an I/O port or directly on the data bus of the system. Using these two latches, the microprocessor can indipendently set both the level and the direction of the current flow in each winding of the stepper motor.

In the 8 bit word of the microprocessor, 7 bits can be used to digitize the sine, cosine functions so achieving 128 levels while the Most Significant Bit can be used as a sign bit (direction).
The 7 bits are indicated as D0.....D6 while the MSB is named phase (Ph).

Three additional pins are present on the GS-D200M for the micro data processing. The data of the microprocessor can be stored into the latches just when the Chip Select pin (CS) is low. The data transfer into the selected modules occurs during the high-to-low transition of the STROBE pin.
The proper latch inside the GS-D200M is selected by the A/B pin: when high the A latch is addressed.
The conversion of the digital information in the latch into an analog signal that sets the current level is performed by a couple of 7-bit D/A converters.
The two analog signals, after proper conditioning for current control, drive two H-powerfet bridges that can directly interface the two motor windings.

CURRENT CONTROL INSIDE THE GS-D200M.

The peak current delivered by the H-bridges can be programmed externally up to 2.5Apk max.
To this purpose a resistor must be connected between the pins REF_{out} and I_{oset}. This resistor fixes the current to voltage conversion of the two D/A converters that employ a current switch approach to reach a setting time of less than 2µs.
The value of the current programming resistor is given by:

$$R_i = (3.2/Ipk - 1)\ k\Omega.$$

where Ipk = phase peak current.

The minimum value of Ri is 280Ω that corresponds to the maximum current of 2.5Apk.
The phase current level control of the GS-D200M is achieved by a chopping mode.
The Pulse Width Modulation (PWM) that could be used to achieve a chopping mode can exhibit some stability problems if the switching duty-cycle exceeds 50%.
For this reason the GS-D200M uses Frequency Modulation switching control.
This techniques uses fixed off duration from the moment the output current exceeds the reference level established by the D/A converters.

Referring to the block diagram of fig. 2, the phase current of each bridge is sensed by R_{sense}, amplified and fed to one input of a comparator, being the other input connected to the D/A output.
When the phase current exceeds the level fixed by the D/A, a monostable pulse generator is triggered by the comparator and it disables the H-bridge for a time duration of 32µs that is fixed inside the module. During the off-time the current decays. At the end of the off-time, a new cycle is started, the H-bridge is enabled again and the phase current starts to rise again according to the L/R time constant of the motor winding. The on-time depends on the supply voltage, the L/R constant and the Electromotive force of the motor.
Therefore the total time (on+off) is never constant and the switching frequency is self adapting to the dynamic behaviour requested by microstepping.

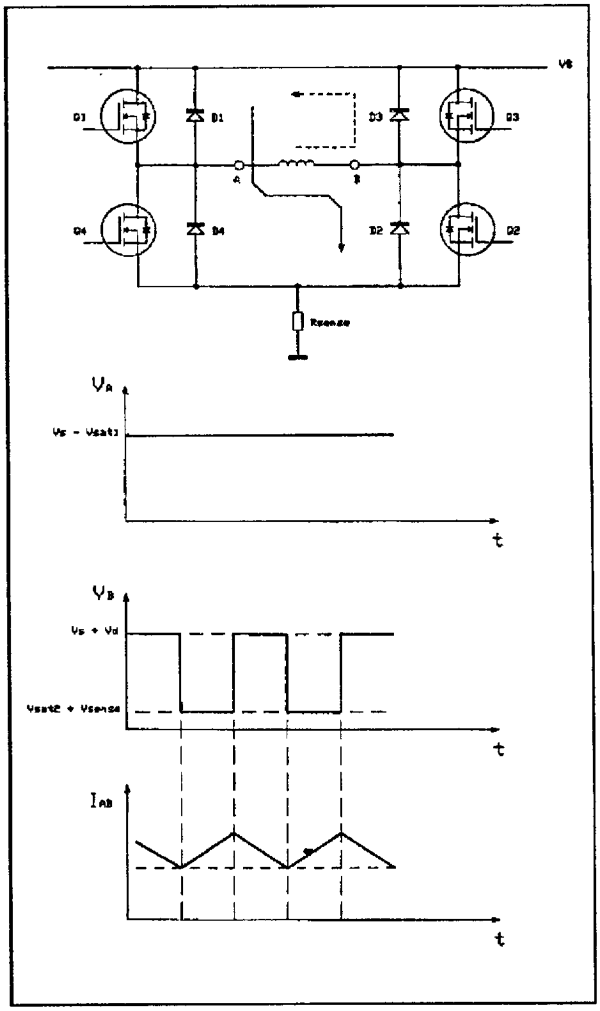
The amount of current decay during the fixed off-time depends on the method used to recirculate the current: slow or fast.

The method for slow decay is shown in fig. 10.
During the on-time both Q1 and Q2 are on. The total voltage V_{AB} applied to the winding is:

$$(V_S - V_{sat1}) - (V_{sat2} + V_{sense})$$

where V_S = supply voltage, V_{sat1} = saturation voltage of Q1, V_{sat2} = saturation voltage of Q2, V_{sense} = voltage drop on the sensing resistor.
The current flow is indicated by the solid line of fig. 10.

Figure 10. Chopper Control with Slow Decay

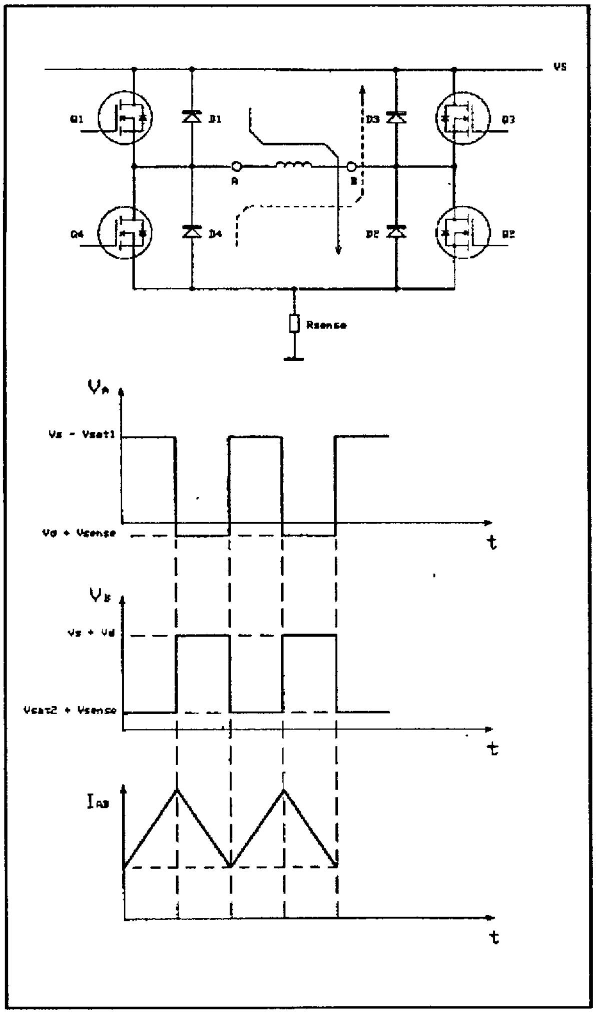


If, during the off-time, Q2 is switched off, the current stored in the winding will flow through D_3 (see dotted line of fig. 10) and V_B will raise the V_S+V_d being V_d the voltage drop of D_3.
The total voltage applied to the winding during the off-time is, therefore, $V_{sat1}+V_d$ and the current decay is slow. The method for fast decay is shown in fig. 11.

During the on-time both Q1 and Q2 are ON as in the previous case.
During the off-time both Q1 and Q2 are switched OFF and the current flows through D_4 and D_3 (dotted line of fig. 11).
During the off-time the voltage applied to the winding is:

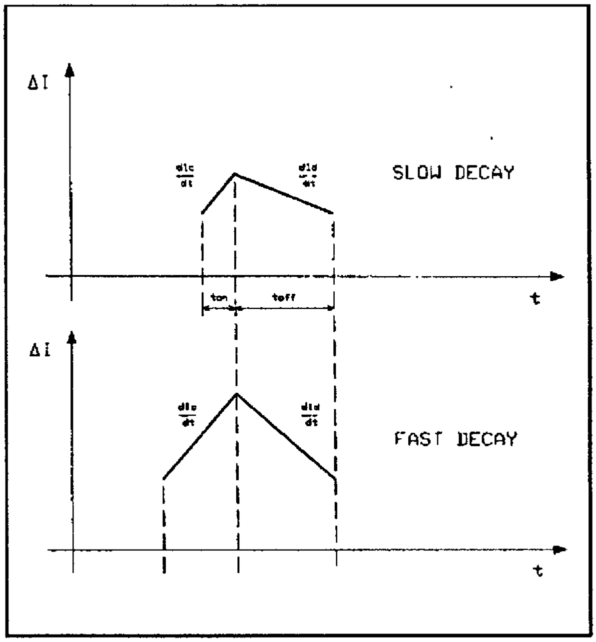
$$(V_S + V_d) - (V_d + V_{sense})$$

Figure 11. Chopper Control with Fast Decay



If the V_d and V_{sense} are negligible compared to V_S, the slope of the current decay is practically equal to the slope of the current rise during the on-time.
The decay can be very fast depending on the value of V_S, R, L and EMF.
Both methods (slow, fast decays) have advantages and disadvantages.
The disadvantage of the fast decay is a higher ripple current due to the chopping action.
The disadvantage of slow decay is the reduced on-time.
In steady state conditions, the amount of decay during off-time is equal to the amount of current rise during the on-time.
Fig. 12 shows a qualitative behaviour of the ripple current in the two cases.
During the off-time the slope dI_d/dt are different because of the different voltage applied to the winding during recirculation.

Figure 12. On-time for Slow and Fast Decay



During the on-time the slope dI_C/dt is the same on both the cases. Being the ripple lower in the slow decay, it takes a shorter time during the on-phase to reach the peak current.

In some application where there is a low back EMF, as it will occur when trying to hold a position and V_{emf} becomes zero, or high supply voltage, the minimum achievable on-time for a slow decay can set a current level that is above the desired current set by the D/A converter.

For a given minimum average phase current I_m, the dutycycle (t_{on}/t = D) is given by the following formula:

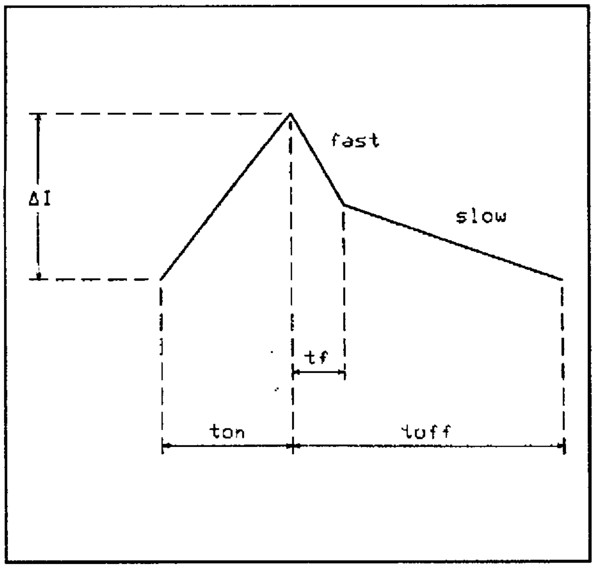
$$I_m = \frac{(V_S - V_{sat1})\,D + (D-1)\,V_d - V_{emf} - V_{sat2} - V_{rsense}}{R_{motor} + R_{sense}}$$

If I_m is very low, D may be prevented to be very low by various delays, etc.
To overcome these problems and to add flexibility to the GS-D200M a mixed decay (recirculation) method as been adopted.

During the off-time, initially a fast decay is imposed on the phase current. The off-time is then completed by a slow decay.
The ripple current behaviour is shown in fig. 13.

An internal monostable is triggered when the current reaches the peak current.
This monostable switches off both Q1 and Q2 (see fig. 11) so forcing a fast decay for a time t_f.

Figure 13. Mixed Decay Method



After t_f, Q1 is turned on again to complete the off-time in a slow mode.

The fast decay time t_f can be programmed by two resistor connected between the R_{tA} and R_{tB} pins to V_{SS} (+5V).
The value of these resistors is given by:

$$R_{tA}, R_{tB} = \left(\frac{t_f}{0.7} - 0.1\right) k\Omega$$

where t_f is in microseconds.

The GS-D200M User is therefore free to select the proper current ripple value that best fits to his/her needs.

USER NOTES

GS-D200M - DAC Operation

GS-D200M has two internal DACs used to set the current in phase AB and in phase CD. The internal DACs are named A and B:

- DAC A set the current in phase CD (pins 23,22)
- DAC B set the current in phase AB (pins 25,24).

To load a digital word, present on D0 - D6 inputs, on DAC A you have to:

- set D0 - D6 inputs, on DAC A (D0 is LSB)
- set input A/B to logic level high
- set CS input to logic level low
- give a STROBE signal.

The digital word set the current at a value given by the relation:

$$Iout = Ipk x \frac{N}{127}$$

where N is the digital value (0 to 127) and Ipk is the maximum current set by means the resistor Ri with the relation:

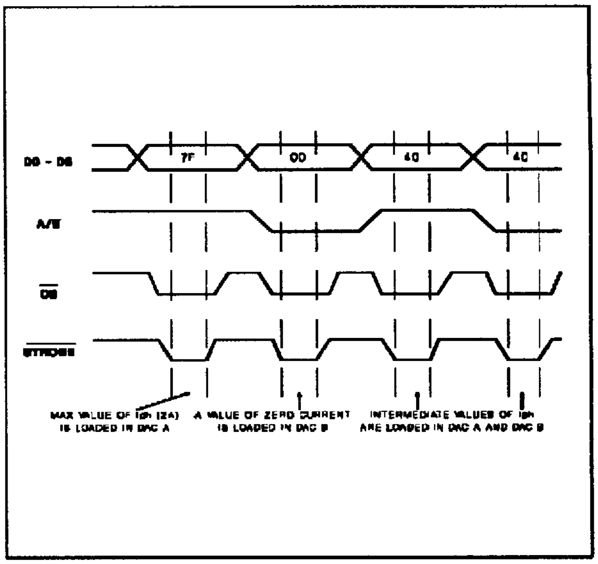
$$Ri = \frac{3.2}{Ipk} - 1 (k\Omega)$$

This means:

- if D0 -D6 are all zeros the phase current is 0 (zero)
- if D0 - D6 are all ones the phase current is the maximum value set by Ri
- other combinations on D0 - D6 give a phase current proportional to the digital value.

Example: Iph= 2A, Ri= 0.6kΩ

Figure 14.

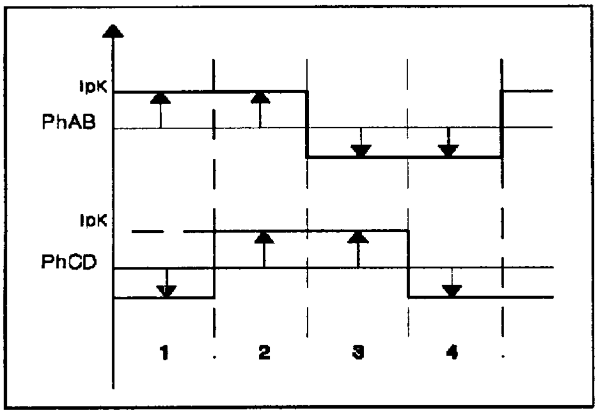


Phase Input (pin 2)

This pin is used to set the direction of the current in the addressed power driver. Usually this pin is connected to the data bus pin named D7. When this input is at logical high level, the current flows from B to A (phase AB) and from C to D (phase CD); when it is at logical low level the current flows from A to B (phase AB) and from D to C (phase CD).

Example: suppose to simulate a full-step moving. The current waveforms present on the phase outputs are shown in fig. 15.

Figure 15.



The arrows show the direction of the current in the phases:

- when phase (D7) = 1

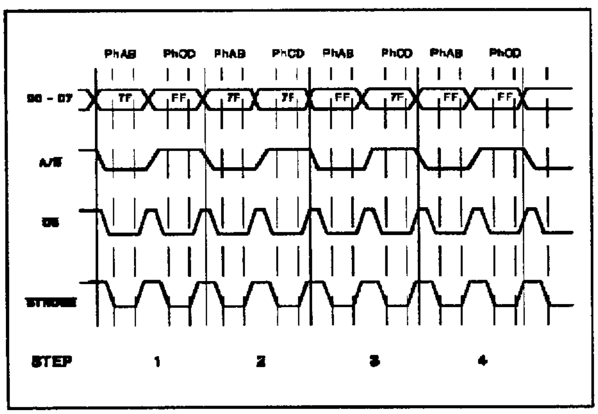
- when phase (D7) = 0

As you can see, the current changes from the maximum value in one way to the maximum value in the opposite way: so the digital inputs D0-D6 will be always at logic level high (7F).

The sequence the user has to load to have the full step mode is:

step	Ph AB			Ph CD		
	D7	D6-D0	D7-D0	D7	D6-D0	D7-D0
1	0	7F	7F	1	7F	FF
2	0	7F	7F	0	7F	7F
3	1	7F	7F	0	7F	7F
4	1	7F	7F	1	7F	FF

Figure 16.



GS-D200M Inhibit/Enable

One pin (DISABLE) is provided to put the two H-bridges in a floating mode.
To operate the GS-D200M this pin must be pulled down.

Supply Voltage

The recommended operating maximum supply voltage V_S is 40V inclusive of the ripple voltage, while for V_{SS} the voltage is 5V±5%.
The two supply voltages must be correctly sequenced to avoid erroneous conditions of the power stages.

The power-up and power-down sequences are:

Power-up
1) V_{SS} (5V) is applied with Disable = High
2) V_S (the motor supply voltage) is applied
3) After 50 ms (power-on reset time) the phase current level can be programmed to the proper level
4) Disable input is brougth low.

Power-down
1) Disable is brougth High
2) V_S is switched off
3) V_{SS} is switched off.

Case Grounding

The module case is internally connected to pin 19, 20 and 26. To obtain an effective EMI shield, the PCB area below the module can be used as a sixth side shield.

Thermal Characteristics

The case-to-ambient thermal resistance of the module is 5°C/W. This produces a 50°C temperature increase of the module surface for a 10W of internal power dissipation. According to ambient temperature and/or to power dissipation, an additional heatsink or forced ventilation may be required.

Supply Line Impedance

The module has an internal capacitor connected accross the supply pins to assure the circuit stability. This capacitor cannot handle large values of high frequency ripple current, and it is permanently damaged if the primary voltage source impedance is not adequate.

The use of a low ESR, high ripple current 470µF capacitor located as close to the module as possible is recommended. Suitable capacitors should have a RMS current capability of 2.5 A_{RMS} with a working voltage of 50 V_{DC} and an ESR of 0,1Ω at 100 kHz. When space is a limit, a 22µF ceramic multilayer capacitor connected across the module input pins must be used.

Module Protection

The GS-D200M outputs are protected against occasional and permanent short circuits of the output pins to the supply voltage.
The thermal protection is activated when, for any reason, the internal junction temperature reaches 150°C. The unit restarts to operate as soon as the junction temperature falls below 130°C.

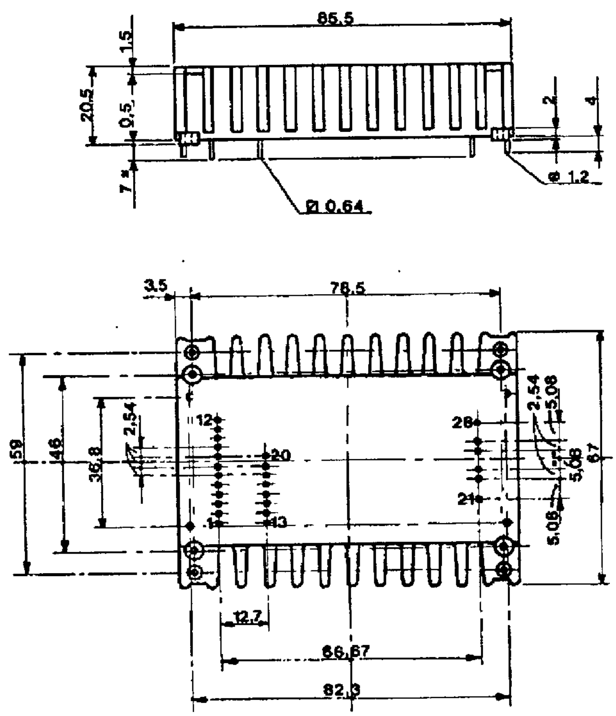
Motor Connection

The motor is usually quite far from the module and long cables are needed to connect the two. The use of a twisted pair cable with appropriate cross section for each motor phase is recommended to minimize DC losses and RFI problems.

Unused Inputs

All the GS-D200M logic inputs, excluding the databus, have a resistive pull-up, and they are in a high logic state when unconnected.

CONNECTION DIAGRAM AND MECHANICAL DATA



Dimensions in mm

Bottomview

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