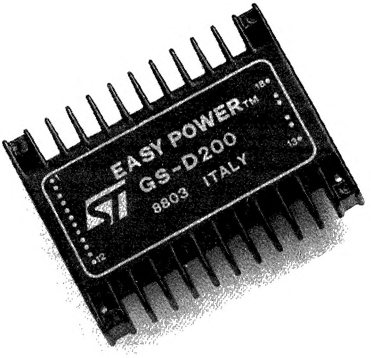
SGS-THOMSON MICROELECTRONICS

GS-D200

SWITCH MODE BIPOLAR STEPPER MOTOR DRIVER MODULE

- NO EXTERNAL COMPONENT REQUIRED
- NORMAL, WAVE, HALF STEP DRIVE CAPABILITY
- INPUTS TTL/CMOS COMPATIBLE
- CHOPPER REGULATION OF MOTOR CURRENT
- PROGRAMMABLE MOTOR CURRENT (2 A max)
- WIDE VOLTAGE RANGE (10–46 V)
- SELECTABLE SLOW/FAST CURRENT DECAY
- SYNCHRONIZATION FOR MULTIPLE APPLICATION
- REMOTE INHIBIT/ENABLE
- HOME POSITION INDICATOR
- OVERTEMPERATURE PROTECTION



ORDER CODE :
GS-D200

DESCRIPTION

The GS-D200 is a complete controller and driver for bipolar stepper motors that directly interfaces a microprocessor and two phase permanent magnet motors.

The motor current is controlled in a chopping mode up to 2 A. High flexibility in use is provided by GS-D200 that, furthermore, reduces the burden on the microprocessor and simplifies the software development in a complete microprocessor controlled stepper motor system.

ABSOLUTE MAXIMUM RATINGS

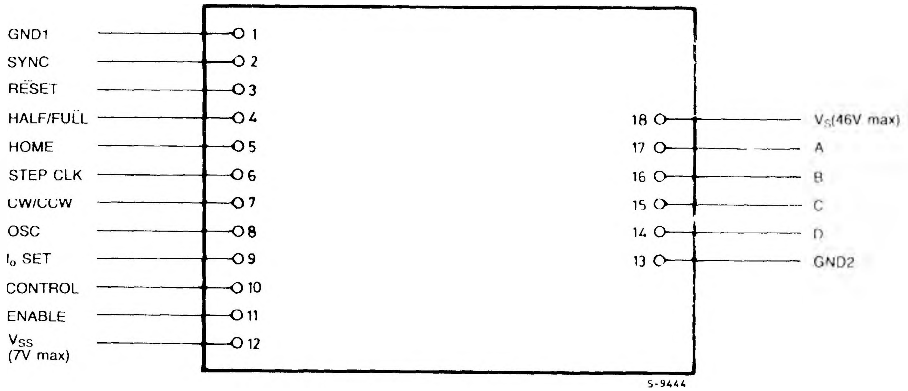
Symbol	Parameter	Value	Unit
V_s	Supply Voltage (pin 18)	48	V
V_{ss}	Logic Supply Voltage (pin 12)	7	V
I_o	Peak Output Current	2	A
T_{stg}	Storage Temperature Range	– 40 to + 105	°C
T_{cop}	Operating Case Temperature Range	– 20 to + 85	°C

Recommended maximum operating input voltage is 46 V.

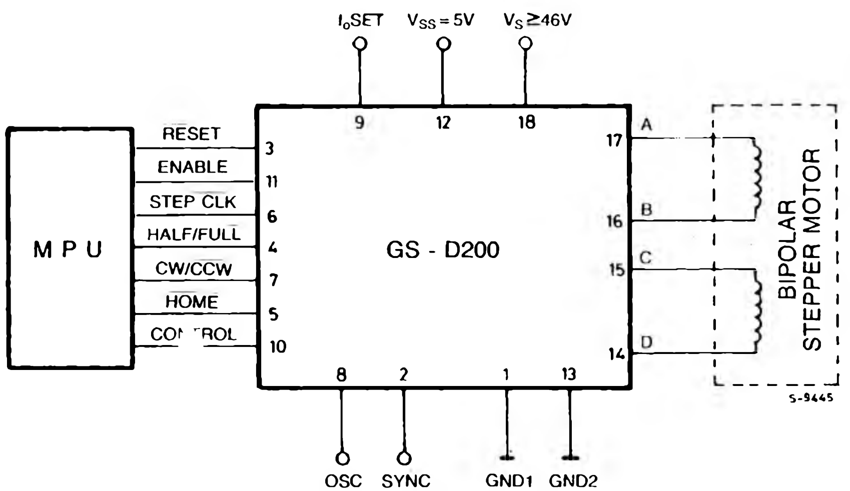
THERMAL DATA

$R_{th\ (c-a)}$	Case-ambient Thermal Resistance	Max	5.0	°C/W

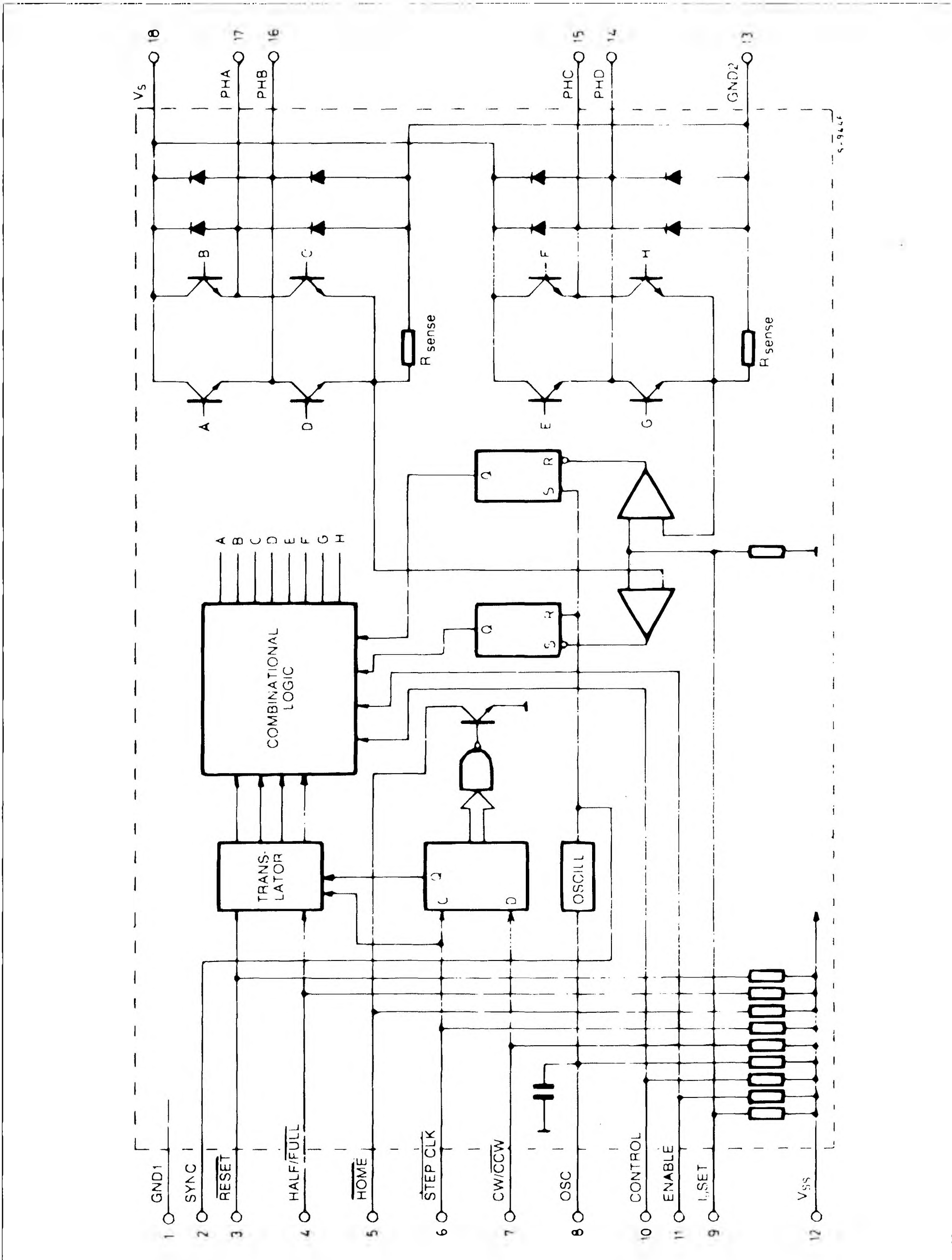
CONNECTION DIAGRAM (top view)



TYPICAL APPLICATION



EQUIVALENT BLOCK DIAGRAM OF GS-D200



PIN FUNCTIONS

Pin	Function
1 – GND1	Common Ground for Low Current Path
2 – SYNC	Output of the Module Chopper Oscillator. Several GS-D200 can be synchronized by connecting together all SYNC pins (see later). An external chopper clock source, if used, must be injected at this pin.
3 – $\overline{\text{RESET}}$	Reset Asynchronous Input. An active low pulse on this input restores the module to the $\overline{\text{HOME}}$ position (ABCD = 0101).
4 – HALF/$\overline{\text{FULL}}$	Half/Full Step Select Input. When high or not connected, it selects half step operation, when low it selects full step operation.
5 – $\overline{\text{HOME}}$	Output that indicates when the module is in its initial state (active low : ABCD = 0101 = state 1). This signal should be ANDed with the output of a mechanical home position sensor of the motor.
6 – $\overline{\text{STEPCLK}}$	A Pulse on this input moves the motor by one step. The step occurs on the rising edge of this signal.
7 – CW/$\overline{\text{CCW}}$	Clockwise/Counterclockwise Direction Control Input. When high or not connected clockwise rotation is selected. Physical direction of motor rotation depends also on connection of windings. Direction can be changed at any time being this signal synchronized inside the module.
8 – OSC	The chopper frequency of the module is internally fixed at ~ 17 KHz. This frequency can be increased by connecting a resistor between this pin and Vss or decreased by connecting a capacitor between this pin and GND1. When multi-GS-D200 configurations must be synchronized, this pin is connected to ground on all but one module.
9 – I_0 SET	The Motor Phas Current is Set at 1 A. This current can be decreased by connecting a resistor between this pin and GND1, or increased by connecting a 10 KΩ min resistor between this pin and V_{SS}.
10 – CONTROL	Control input that defines the motor current decay inherent to chop mode control. When low, a fast decay is obtained ; when high, or not connected, slow current decay is imposed to the motor current.
11 – ENABLE	Module Enable Input. When low the module is inhibited. When high or not connected the module is active.
12 – V_{SS}	5 V Supply Input. Maximum Voltage must not exceed 7 V.
13 – GND2	Common Ground for High Current Path
14 – D	Phase D Output
15 – C	Phase C Output
16 – B	Phase B Output
17 – A	Phase A Output
18 – V_S	Module Supply Voltage. Maximum voltage must not exceed 46 V.

ELECTRICAL CHARACTERISTICS (T_{amb} = 25 °C unless otherwise specifed)

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Unit
V_s	Supply Voltage	Pin 18	10		46	V
V_{ss}	Supply Voltage	Pin 12	4.75	5	5.25	V
I_s	Quiescent Supply Current	Pin 18 I_{out} = 0 V_s = 42 V		15	20	mA
I_{ss}	Quiescent Supply Current	Pin 12. All Input High I_{out} = 0 V_{ss} = 5 V		60		mA
V_i	Input Voltage	Pin 3, 4, 6, 7, 10 Low High	 2.0		0.8 V_{ss}	V V
I_i	Input Current	Pin 5, 4, 6, 7, 10 V_i = Low V_i = High			0.6 10	mA µA
V_{en}	Enable Input Votlage	Pin 11 Low High	 2.0		0.8 V_{ss}	V V
I_{en}	Enable Input Current	Pin 11 V_{en} = L V_{en} = H			0.6 10	mA µA
V_{home}	Home Output Voltage	Pin 5 Low I_{home} = 5 mA High			0.4 V_{ss}	V V
V_{sat}	Source Saturat. Voltage	Pin 14, 15,16, 17 I_o = 1 A			1.8	V
V_{sat}	Source Saturat. Voltage	Pin14, 15, 16, 17 I_o = 1 A			1.8	V
f_c	Chopper Freq.			17		KHz
f_{clk}	Stepclk Width	Pin 6 See Fig. a	0.5			µs
t_s	Set Up Time	See Fig. a	1.0			µs
t_h	Hold Time	See Fig. a	1.0			µs
t_R	Reset Width	See Fig. b	1.0			µs
t_{Rclk}	Reset to Clock Set Up Time	See Fig. b	1.0			µs

Figure a.

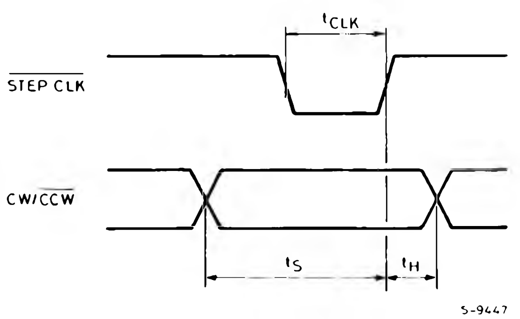
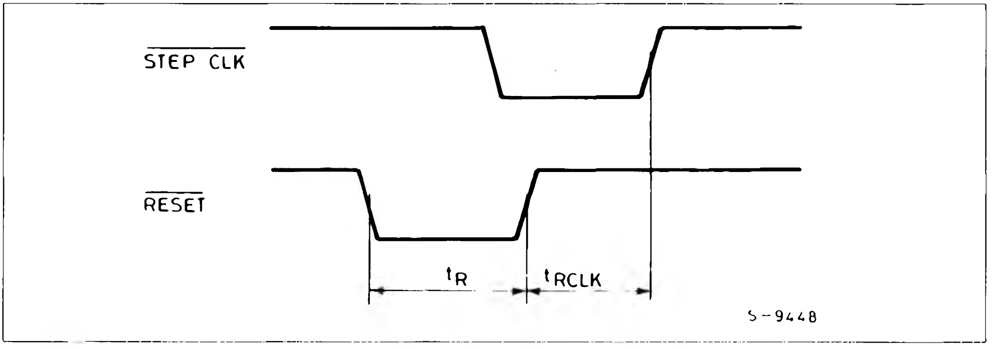


Figure b.



MODULE OPERATION

The GS-D200 is a complete bipolar stepper motor driver that incorporates all the small signal and power functions to directly interface a microprocessor and a two phase permanent magnet motor (see the typical application). Very few information must be delivered by the microprocessor to the module :

- step clock
- direction (clockwise or counterclockwise)
- mode (half or full step)
- reset and enable
- current decay (slow or fast)

Based on this information, the module generates the proper four phases sequence to directly drive a two phase bipolar motor. Therefore the GS-D200 greatly simplifies the task of the microprocessor and of the system programmer.

No external component is needed to operate the GS-D200. However, to add flexibility in use, some internally set functions can be modified externally, like the maximum current flowing through the motor windings and the switching frequency of the current chopper, by addition of few inexpensive passive components (resistor and capacitor).

If any of logic input is left open, the module forces them to high level.

The GS-D200 is housed in a metal case that provides heatsink and shielding against radiated EMI. The thermal resistance case to ambient is about 5 °C/W. This means that for each watt of internal power dissipation the case temperature is + 5 °C above ambient temperature. It is recommended to keep the case temperature below 85 °C in operating conditions.

According to ambient temperature and / or to power dissipation, an additional heatsink may be required : the mounting of optional heatsink is made easy by the four holes provided on the top of the metal case.

The GS-D200 incorporates a thermal protection that switches off the power stages when the junction temperature of active components reaches 150 °C.

To keep the power dissipation to a minimum, two level supply voltages must be applied to the module : 5 V for logic functions and V_S from 10 to 46 V for power section.

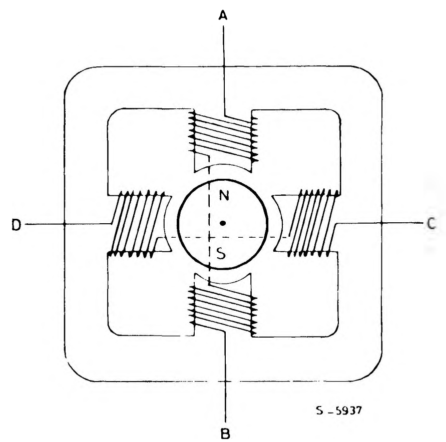
A. BIPOLAR STEPPER MOTOR BASICS

Simplified to the bare essentials, a bipolar permanent magnet motor consists of a rotating-permanent magnet surrounded by stator poles carrying the windings (fig. 1).

Bidirectional drive current is imposed on windings A-B and C-D and the motor is stepped by commutating the voltage applied to the windings in sequence.

For a motor of this type there are three possible drive sequences.

Figure 1 : Simplified Bipolar Two Phase Motor.



A. 1. ONE-PHASE-ON OR WAVE DRIVE

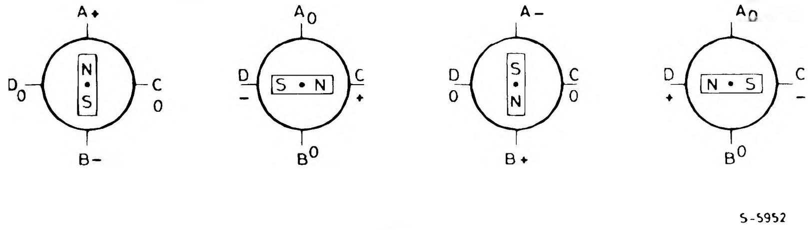
Only one winding is energized at any given time according to the sequence :

AB - CD - BA - DC

(BA means that the current is flowing from B to A).

Fig. 2 shows the sequence for a clockwise rotation and the corresponding rotor position.

Figure 2 : One-phase-on (wave mode) drive.



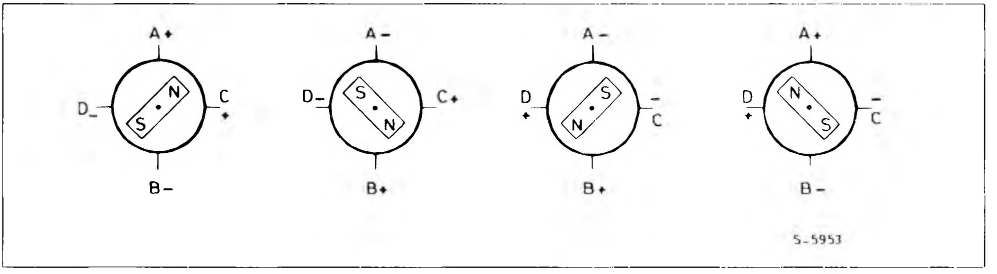
A. 2. TWO-PHASE-ON OR NORMAL DRIVE

This mode gives the highest torque since two windings are energized at any given time according to the sequence (for clockwise rotation).

AB & CD ; CD & BA ; BA & DC ; DC & AB

Fig. 3 shows the sequence and the corresponding position of the rotor.

Figure 3 : Two-phase-on (normal mode) drive.



A. 3. HALF STEP DRIVE

This sequence halves the effective step angle of the motor but gives a less regular torque being one winding or two windings alternatively energized. Eight steps are required for a complete revolution of the rotor.

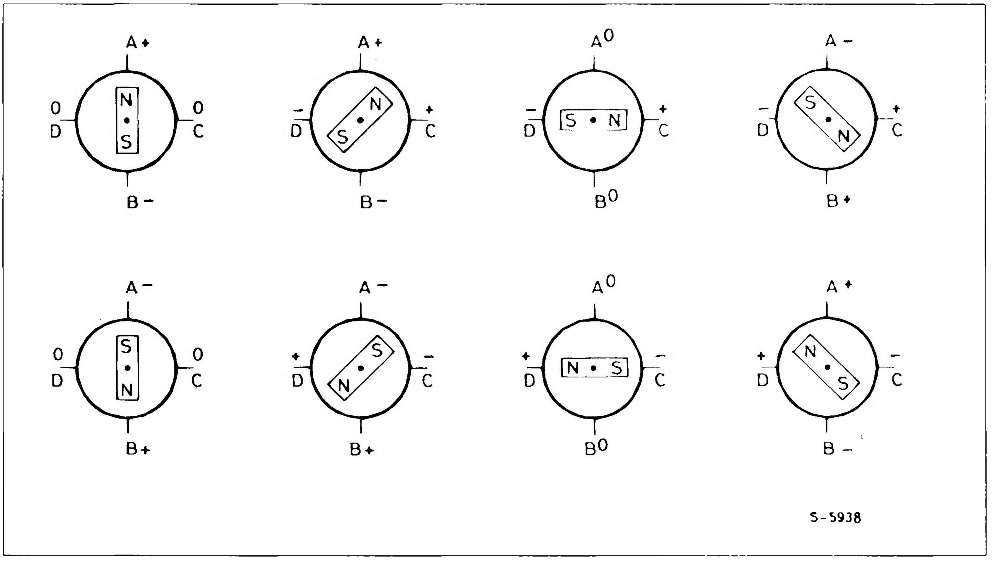
The sequence is :

AB ; AB & CD ; CD ; CD & BA ; BA ; BA & DC ; DC ; DC & AB

as shown in fig. 4.

By the configurations of fig. 2, 3, 4 the motor would have a step angle of 90 ° (or 45 ° in half step). Real motors have multiple poles pairs to reduce the step angle to a few degrees but the number of windings (two) and the drive sequence are unchanged.

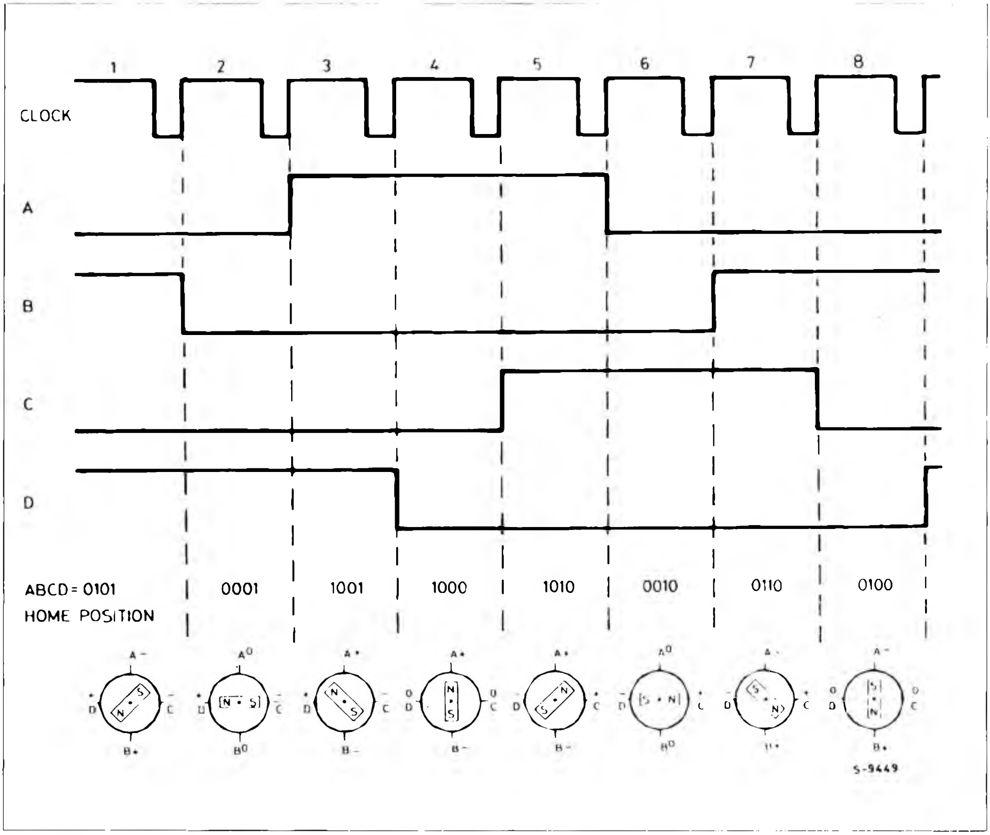
Figure 4 : Half Step Sequence.



B. PHASE SEQUENCE GENERATION INSIDE THE GS-D200

The GS-D200 contains a three bit counter plus some combinational logic which generate suitable phase sequences for half step, wave and normal full step drive. This 3 bit counter generates a basic eight-step Gray code master sequence as shown in fig. 5. To select this sequence, that corresponds to half step mode, the HALF/FULL input (pin 4) must be kept high or left open.

Figure 5 : The Eight Step Master Sequence Corresponding to Half Step Mode.



The full step mode (normal and wave drive) are both obtained from the eight step master sequence by skipping alternate states. This is achieved by forcing the step clock to bypass the first stage of the 3 bit counter. The least significant bit of this counter is not affected and therefore the generated sequence depends on the state of the counter when full step mode is selected by forcing pin 4 (HALF/FULL) low.

If full step is selected when the counter is at any odd-numbered state, the two-phase-on (normal mode) is implemented (see fig. 6).

On the contrary, if the full mode is selected when the counter is at an even-numbered state, the one-phase-on (wave drive) is implemented (see fig. 7).

Figure 6 : Two-phase-on (normal mode) drive.

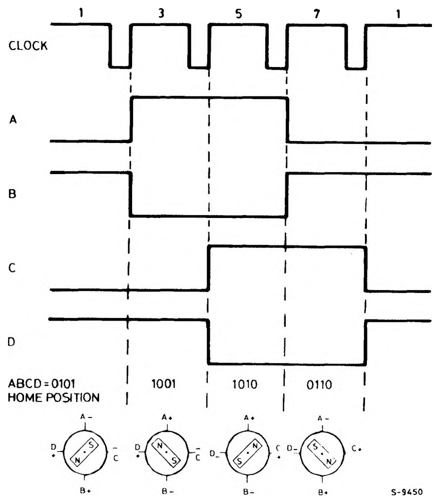
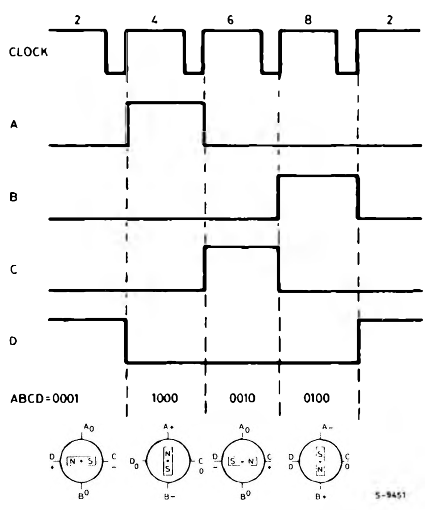


Figure 7 : One-phase-on (wave mode) drive.



C. RESET, ENABLE AND HOME SIGNALS

The $\overline{\text{RESET}}$ is an asynchronous reset input which restores the module to the home position (state 1 : ABCD = 0101). Reset is active when low.

The $\overline{\text{HOME}}$ output signals this condition and it is intended to be ANDed with the output of a mechanical home position sensor.

The ENABLE input is used to start up the module after the system initialization. ENABLE is active when high or open.

D. MOTOR CURRENT REGULATION

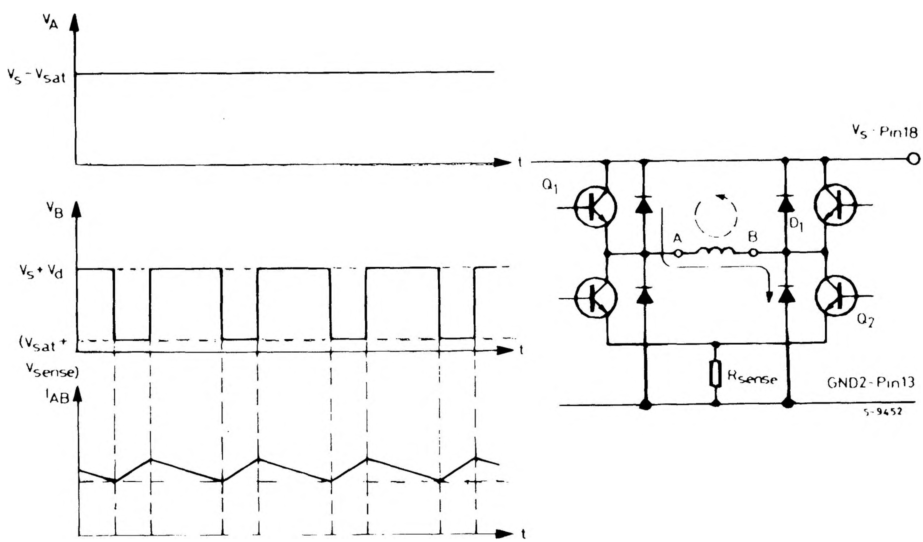
The two bipolar winding currents are controlled by two internal choppers in a PWM mode to obtain good speed and torque characteristics.

An internal oscillator supplies pulses at the chopper frequency to both choppers.

When the outputs are enabled, the current through the windings raises until a peak value set by I_0SET and R_{sense} (see the equivalent block diagram) is reached. At this moment the outputs are disabled and the current decays until the next oscillator pulse arrives.

The decay time of the current can be selected by the CONTROL input (pin 10). If the CONTROL input is kept high or open the decay is slow, as shown in fig. 8, where the equivalent power stage of GS-D200, the voltages on A and B are shown as well as the current waveform on winding AB.

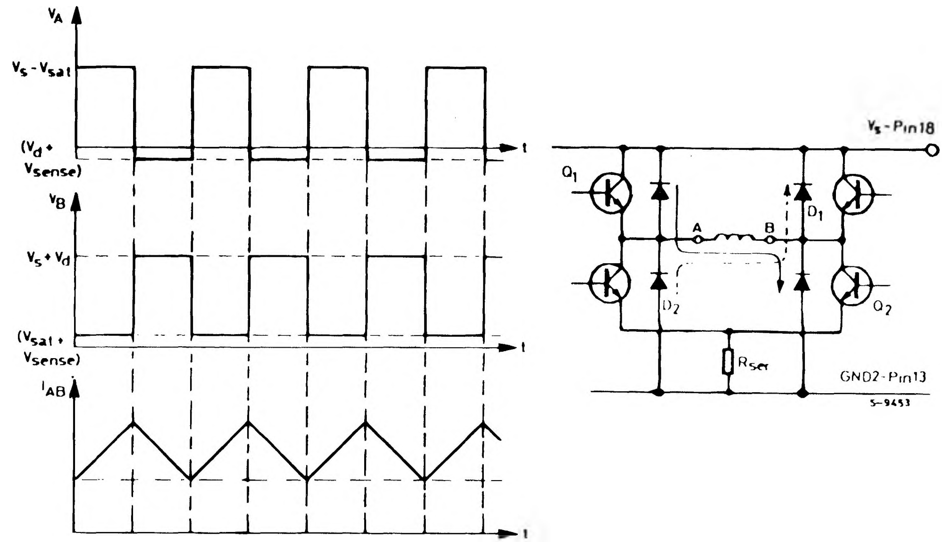
Figure 8 : Chopper Control with Slow Decay.



———— drive current (Q_1, Q_2, ON)
------------- recirculation current (Q_1, ON, Q_2, OFF, D_1, ON)

When the CONTROL input is forced low, the decay is fast as shown in fig. 9.

Figure 9 : Chopper Control with Fast Decay.



——— drive current (Q_1, Q_2, ON)
------------ recirculation current (Q_1, Q_2, OFF, D_1, D_2, ON)

The CONTROL input is provided on GS-D200 to allow maximum flexibility in application.

If the GS-D200 must drive a large motor that does not store much energy in the windings, the chopper frequency must be decreased : this is easily obtained by connecting an external capacitor between OSC pin and GND1.

In these conditions a fast decay (CONTROL LOW) would impose a low average current and the torque could be inadequate. By selecting CONTROL HIGH, the average current is increased thanks to the slow decay

E. MODULE PROGRAMMING

When no external component is used, the GS-D200 is set at the following conditions :

$I_{outpeak} \cong 1$ A

f_c chopper frequency $\cong$ 17 KHz

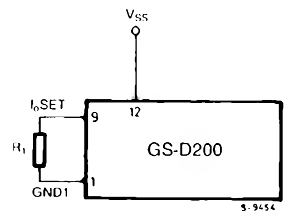
By addition of inexpensive passive components the working conditions can be modified as follows.

E.1. OUTPUT CURRENT PROGRAMMING

The output peak current (initially set at 1 A) can be re-programmed by addition of an external resistor.

If a lower peak current is desired, a resistor R1 must be connected between I_0SET and GND1 as shown in fig. 10.

Figure 10 : Peak Current Reduction.



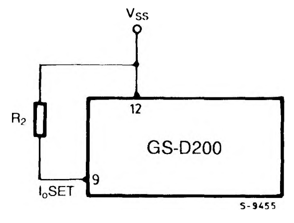
The value of output current, for V_{SS} = 5 V, is related to the value of R1 by

$$I_{out} = \frac{11.2}{11.2 + \frac{12}{R1}}$$ A where R1 is in KΩ

For example, for R1 = 1 KΩ $I_{out} \cong 0.5$ A.

If a higher peak current is needed, a resistor R2 must be connected between I_{oSET} and V_{SS} as shown in fig. 11.

Figure 11 : Peak Current Increase.



The output current, for V_{SS} = 5 V, is related to the value of R2 by

$$I_{out} = \frac{120 + 12 \bullet R2}{12 + 11.2 \bullet R2}$$ A where R2 is in KΩ

For example, for R2 = 24 KΩ $I_{out} \cong 1.45$ A

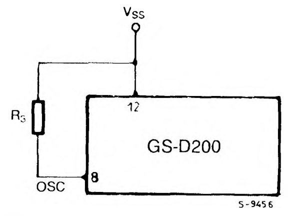
Minimum value of R2 is 10 kΩ. This current programmability can be used in half step sequence to increase the current when only one phase is on : a more regulator torque is so obtained.

E.2. CHOPPER FREQUENCY PROGRAMMING

The chopper frequency is internally set at about 17 KHz. This frequency can be changed by addition of external components as follows.

To increase the chopper frequency a resistor R3 must be connected between OSC pin and V_{SS} as shown in fig. 12.

Figure 12 : Chopper Frequency Increase.



The new chopper frequency is given by :

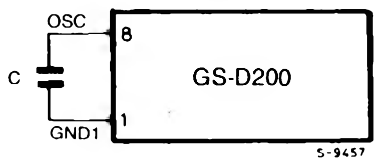
$f_C = 17\ (1 + \frac{18}{R3})$ KHz where R3 is in KΩ

For example, if V_{SS} = 5 V and R3 = 18 KΩ

$f_C \cong 34$ KHz

To decrease the chopper frequency a capacitor C must be connected between OSC pin and GND1 as shown in fig. 13.

Figure 13 : Chopper Frequency Decrease.



The new chopper frequency is given by :

$$f_C = \frac{80.5}{4.7 + C} \text{ KHz where C is in nF}$$

For example, if V_{SS} = 5 V and C = 4.7 nF, $f_C \cong 8.5$ KHz.

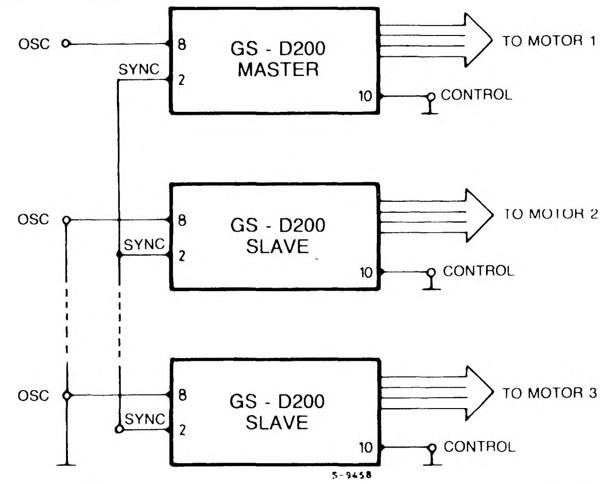
F. MULTI MODULES APPLICATION

In complex systems, many motors must be controlled and driven. In such a case more than one GS-D200 must be used.

To avoid chopper frequencies noise and beats, all the GS-D200 should be synchronized.

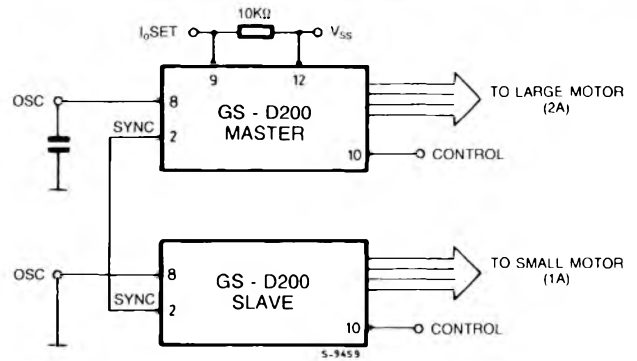
If all the motors are relatively small, the fast decay may be used, the chopper frequency does not need any adjustement and fig. 14 shows how to synchronize several modules.

Figure 14 : Multimotor Sybchronization. Small Motor and Fast Current Decay.



When at least one motor is relatively large a lower chopper frequency and a slow decay may be required. In such a case the overall system chopper frequency is determined by the largest motor in the system as shown in fig. 15.

Figure 15 : Multimotor Synchronization. Large and Small Motor. Slow Current Decay.



G.THERMAL OPERATING CONDITIONS

In many cases the GS-D200 module does not require any additional cooling because the dimensions and the shape of the metal box are studied to offer the minimum possible thermal resistance case-to-ambient for a given volume.

It should be remembered that the GS-D200 module is a power device and, depending on ambient temperature, an additional heath-sink or forced ventilation or both may be required to keep the unit within safe temperature range. ($Tcase_{max}$ < 85 °C during operation).

The concept of maximum operating ambient temperature is totally meaningless when dealing with power components because the maximum operating ambient temperature depends on how a power device is used.

What can be unambiguously defined is the case temperature of the GS-D200 module.

To calculate the maximum case temperature of the module in a particular applicative environment the designer must know the following data :

- Input voltage
- Motor phase current
- Motor phase resistance
- Maximum ambient temperature

From these data it is easy to determine whether an additional heath-sink is required or not, and the relevant size i.e. the thermal resistance.

The step by step calculation is shown for the following example :

V_{in} = 40 V, I_{phase} = 1 A, Rph Phase resistance = 10 Ω, Max. T_{amb} = 50 °C

G1. Calculate the power dissipated from the indexer logic and the level shifter (see electrical characteristics) :

$$P_{logic} = (5\ V\ .\ 60\ mA) + (40\ V\ .\ 20\ mA) = 1.1\ W$$

G2. Calculate the average voltage across the winding resistance :

$$V_{out} = (Rph\ .\ I_{out}) = 10\ \Omega\ .\ 1\ A = 10\ V$$

G3. Calculate the required ON duty cycle (D.C.) of the output stage to obtain the average voltage (this D.C. is automatically adjusted by the GS-D200) :

$$D.C. = \frac{V_{out}}{V_{in}} = \frac{10}{40} = 0.25$$

G4. Calculate the power dissipation of the GS-D200 output power stage. The power dissipation depends on two main factors :

- the selected operating mode (FAST or SLOW DECAY)
- the selected drive sequence (WAVE, NORMAL, HALF STEP)

G4.1 FAST DECAY. For this mode of operation, the internal voltage drop is $Vsat_{source} + Vsat_{sink}$ during the ON period i.e. for 25 % of the time.

During the recirculation period (75 % of the time), the current recirculates on two internal diodes that have a voltage drop V_d = 1 V, and the internal sense resistor (0.5 Ω). For this example, by assuming maximum values for conservative calculations, the power dissipation during one cycle is :

$P_{pw} = 1.1 \bullet [2\ V_{sat} \bullet Iph \bullet DC + 2\ V_d \bullet I_{ph} \bullet (1 - DC) + 0.5 \bullet I_{ph}]$

$P_{pw} = 1.1 \bullet [2 \bullet 1.8 \bullet 1 \bullet 0.25 + 2 \bullet 1 \bullet 1 \bullet 0.75 + 0.5 \bullet 1]$

$P_{pw} = 1.1 \bullet [0.9 + 1.5 + 0.5] = 3.19\ W$

The factor 1.1 takes into account the power dissipation during the switching transient.

G4.2 SLOW DECAY. The power dissipation during the ON period is the same. The RECIRCULATION is made internally through a power transistor ($Vsat_{sink}$) and a diode. The power dissipation is, therefore :

$P_{pw} = 1.1 \bullet [2\ V_{sat} \bullet I_{ph} \bullet DC + (V_{sat} + V_d) \bullet I_{ph} \bullet (1-DC)]$

$P_{pw} = 1.1 \bullet [2 \bullet 1.8 \bullet 1 \bullet 0.25 + (1.8 + 1) \bullet 1 \bullet 0.75]$

$P_{pw} = 1.1 \bullet [0.9 + 2.1] = 3.3\ W$

G4.3 WAVE MODE. When operating in this mode the power dissipation is given by values of 4.1 or 4.2 paragraphes, because one phase is energized at any given time.

G4.4 NORMAL MODE. At any given time, two windings are always energized. The power dissipation of the power output stage is therefore multiplied by a factor 2.

G4.5 HALF STEP. The power sequence, one phase ON, two phase ON forces the power dissipation to be 1.5 times higher than in WAVE MODE when the motor is running. In stall condition the worst case for power dissipation is with two phase ON i.e. a power dissipation as in NORMAL MODE.

The following table summarizes the power dissipations of the output power stage of the GS-D200 when running for this example :

	Wave	Normal	Half Step
Fast Decay	3.19 W	6.38 W	6.38 W
Slow Decay	3.30 W	6.60 W	6.60 W

G5. Calculate the total power dissipation for the GS-D200 :

$$P_{tot} = P_{logic} + P_{pw}$$

In this example, for slow decay and normal mode

$$P_{tot} = 1.1 + 6.6 = 7.7\ W$$

G6. The case temperature can now be calculated :

$T_{case} = Tamb + (P_{tot} \bullet R_{th}) = 55 + (7.7 \bullet 5) = 93.5\ °C$

G7. If the calculated case temperature exceeds the maximum allowed case temperature, as in this example, an external heat-sink is required and the thermal resistance can be calculated according to :

$$Rth_{tot} = \frac{T_{cmax} - Tamb}{P_{tot}} = \frac{85 - 55}{7.7} = 3.9\ °C/W$$

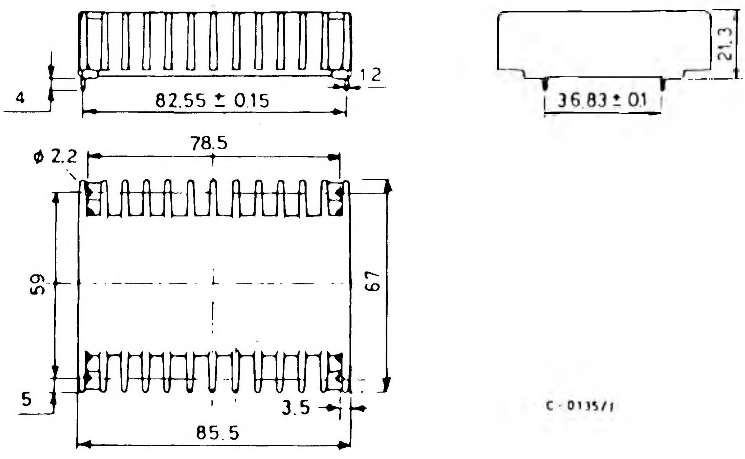
and then

$$Rth_{hs} = \frac{Rth - Rth_{tot}}{Rth - Rth_{tot}} = \frac{5 \bullet 3.9}{5 - 3.9} = 17.7\ °C/W$$

The following table gives the thermal resistance of some commercially available heath-sinks that fit on the GS-D200 module.

Manufacturer	Part Number	R_{th} (°C/W)	Mounting
Thermalloy	6177	3	Horizontal
Thermalloy	6152	4	Vertical
Thermalloy	6111	10	Vertical
Fischer	SK18	3	Vertical
Assman	V5440	4	Vertical
Assman	V5382	4	Horizontal

MECHANICAL DATA (dimensions in mm)



MOTHER BOARD LAYOUT