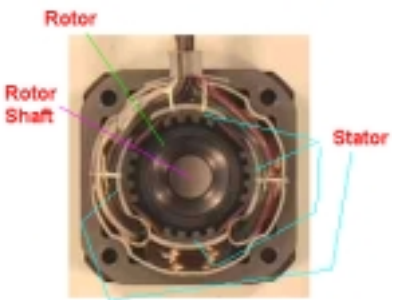
Motor Control

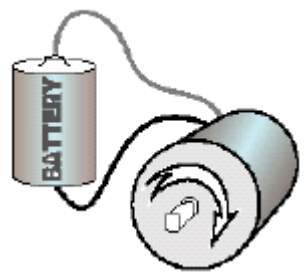
WWW.MWFTR.COM

Dr. Charles J. Kim

Department of Electrical and Computer Engineering

Howard University

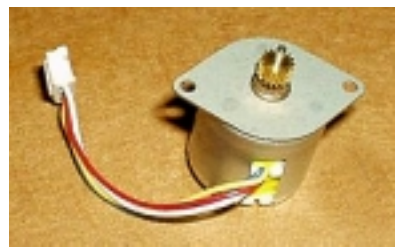




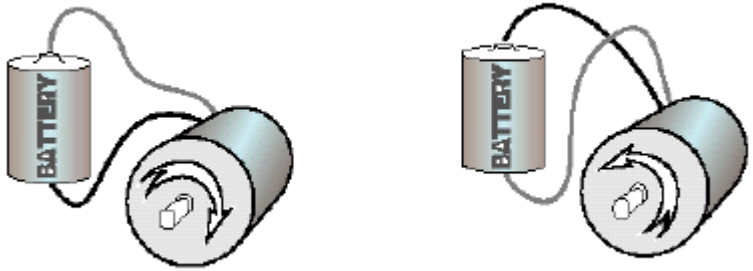
EECE691: Embedded Computing

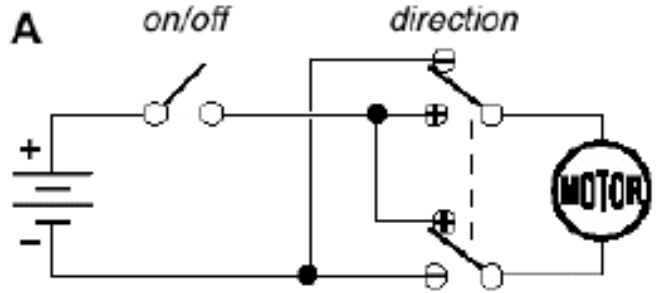
Motors and Control Methods

- DC Motor Control
  - Forward, Reverse, Stop
  - Control by Manual Switch
  - Control by Relay
  - Control by Transistor
  - Control by H-Bridge
  - Control by Motor Driver
- DC Stepper Motor Control
  - Bipolar Stepper Motor
    - Control Driver
  - Unipolar Stepper Motor
    - Control Driver

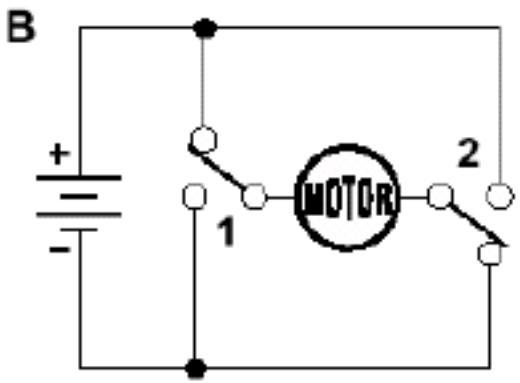


DC Motors and Manual Control



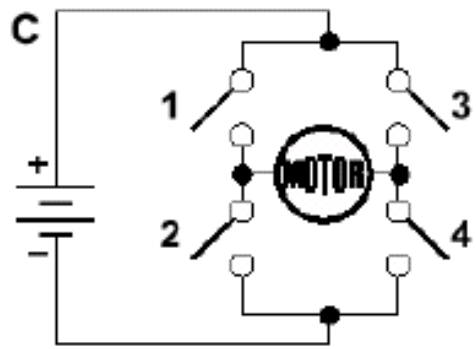


SPST switch controls on/off;
DPDT switch sets direction



1 UP, 2 UP	= STOP (BRAKE)
1 UP, 2 DOWN	= FORWARD
1 DOWN, 2 UP	= REVERSE
1 DOWN, 2 DOWN	= STOP (BRAKE)

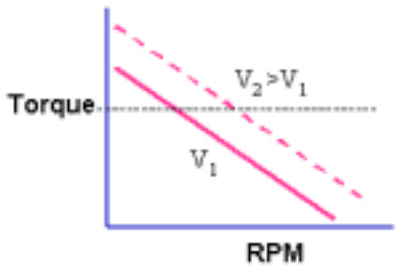
A pair of SPDT switches controls
on/off and direction; brakes to a stop



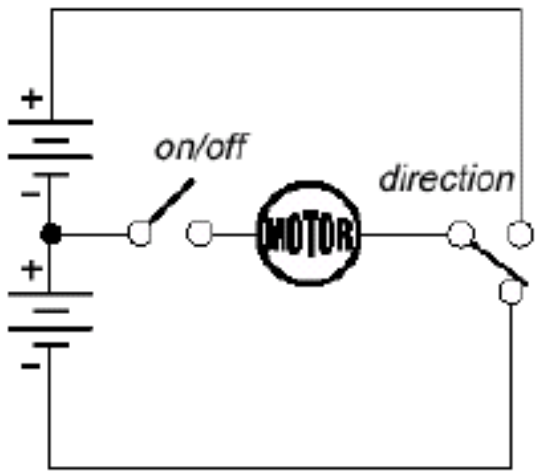
ALL OFF = STOP (LOOSE)
1 + 4 ON = FORWARD
2 + 3 ON = REVERSE
1 + 3 ON = STOP (BRAKE)
2 + 4 ON = STOP (BRAKE)
1 + 2 ON = *NOT ALLOWED*
3 + 4 ON = *NOT ALLOWED*

Four SPST switches (H bridge)
control on/off, direction & braking

DC Motors and Manual Control

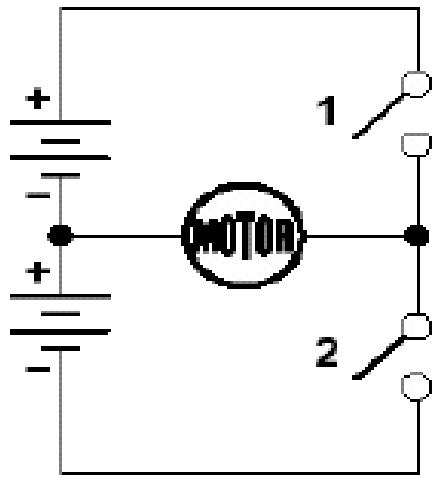


D



SPST switches controls on/off;
SPDT sets direction

E



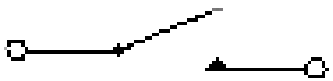
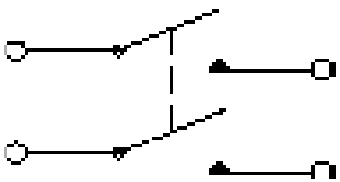
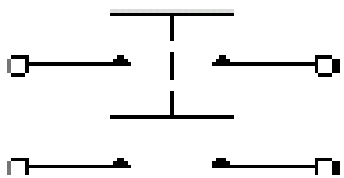
BOTH OFF = STOP (LOOSE)
1 ON = FORWARD
2 ON = REVERSE
1 + 2 ON = *NOT ALLOWED*

Two SPST switches (half bridge)
control on/off & direction

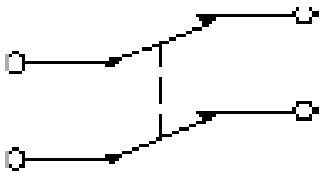
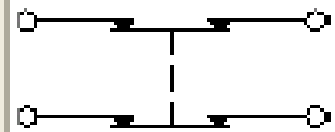
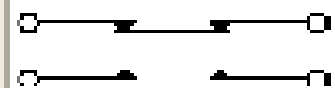
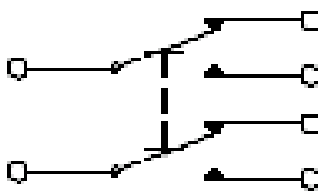
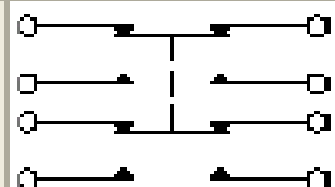
Selector Switch

- SPST: Single pole single throw.
  SPDT: Single pole double throw.
  DPST: Double pole single throw.
  DPDT: Double pole double throw
  DP3T: Double pole three throw.
  DP4T: Double pole four throw.
  3PDT: Three pole double throw.
  3P3T: Three pole three throw.

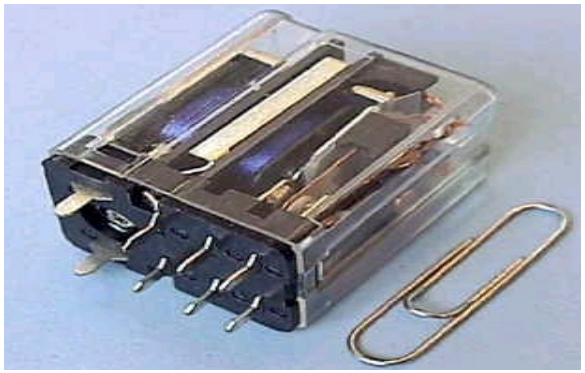
Selector Switch Diagram

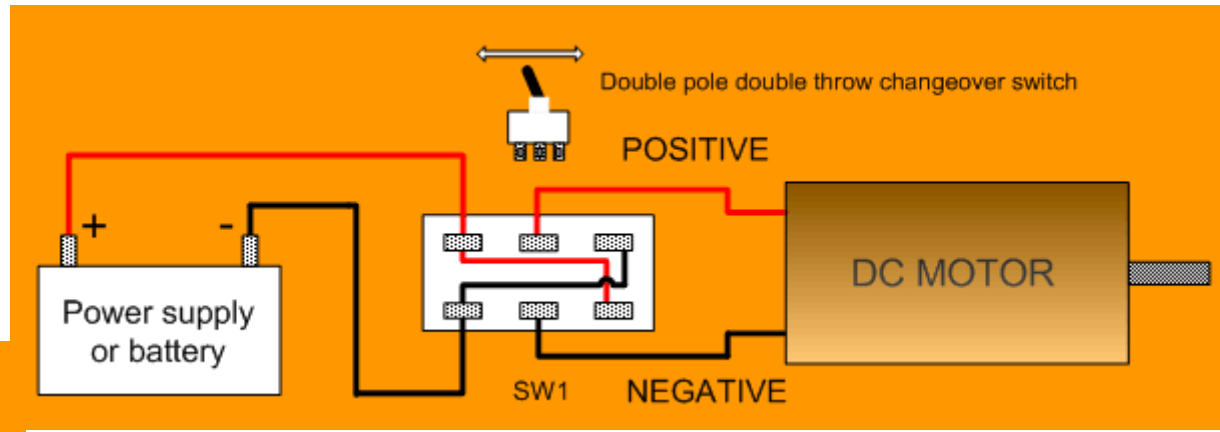
 **Form A - SPST-NO** Single Pole - Single Throw Normally Open	 **Form X - SPST-DB-NO** Single Pole - Single Throw Double Break - Normally Open
 **Form AA - DPST-NO** Double Pole - Single Throw Normally Open	 **Form XX - DPST-DB-NO** Double Pole - Single ThrowDouble Break - Normally Open
 **Form B - SPST-NC** Single Pole - Single Throw Normally Closed	 **Form Y - SPST-DB-NC** Single Pole - Single Throw Double Break - Normally Closed

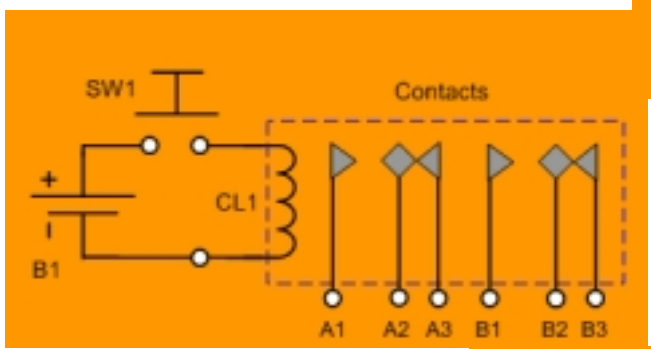
Switch Diagram

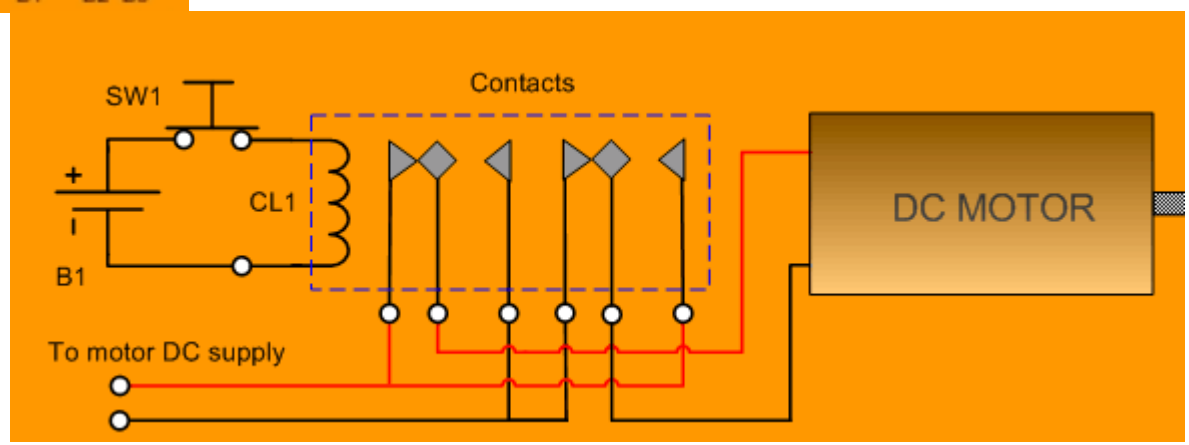
 **Form BB - DPST-NC** Double Pole - Single Throw Normally Closed	 **Form YY - DPST-DB-NC** Double Pole - Single Throw Double Break - Normally Closed
 **Form C - SPDT** Single Pole - Double Throw	 **Form Z - SPDT-DB** Single Pole - Double Throw Double Break
 **Form CC - DPDT** Double Pole - Double Throw	 **Form ZZ - DPDT-DB** Double Pole - Double Throw Double Break

DC Motor Control by Relay

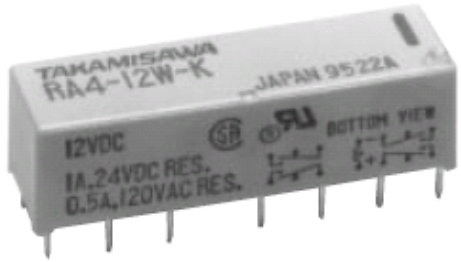






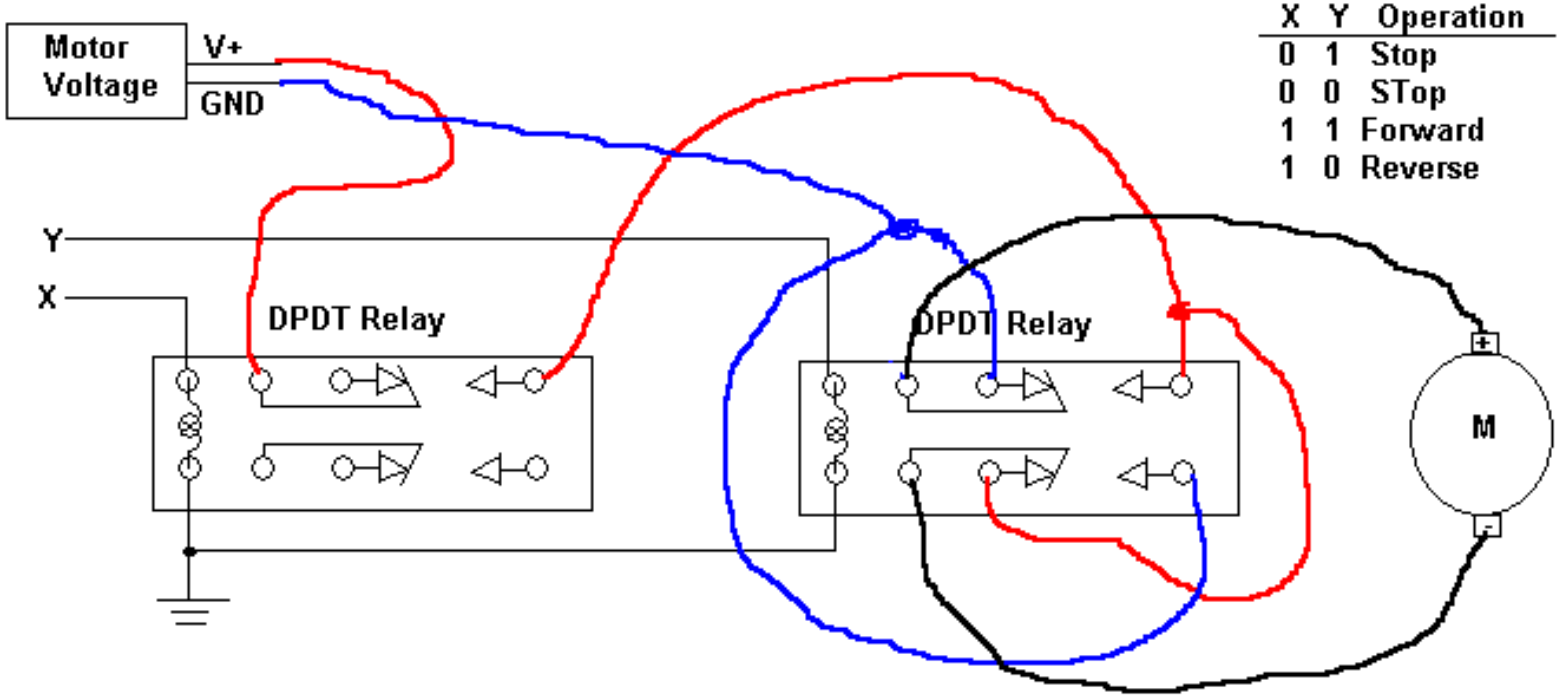


Motor Control using a Relay



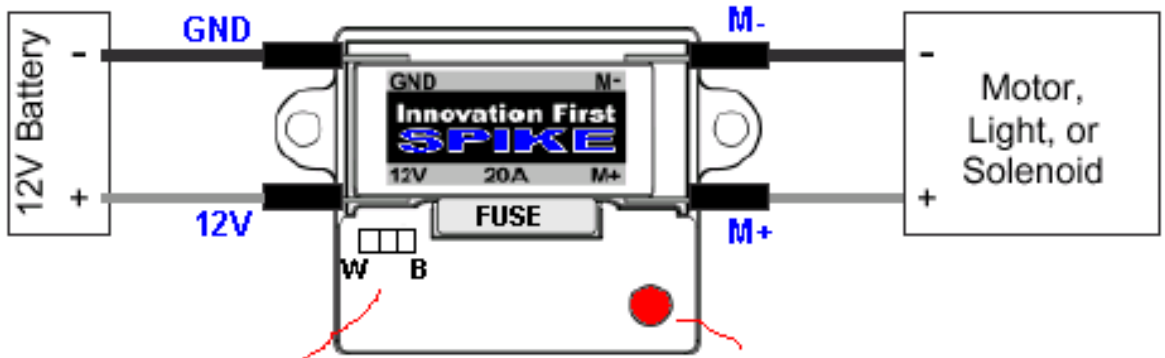
4 POLES—1 to 2 A

X	Y	Operation
0	1	Stop
0	0	STop
1	1	Forward
1	0	Reverse



*NOTE: Action Y first, then apply X

DC Motor Control using High Current Relay



Connector Details

			M+	M-	Lamp Color
GND	GND	GND	GND	GND	Orange
GND	+5V	GND	+12V	GND	Green
+5V	GND	GND	GND	+12V	Red
+5V	+5V	GND	+12V	+12V	Off

*NOTE: Avoid this combination

Rev control

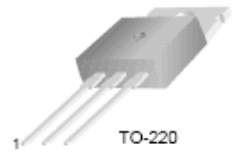
Fwd Control

DC Motor Control with Transistor

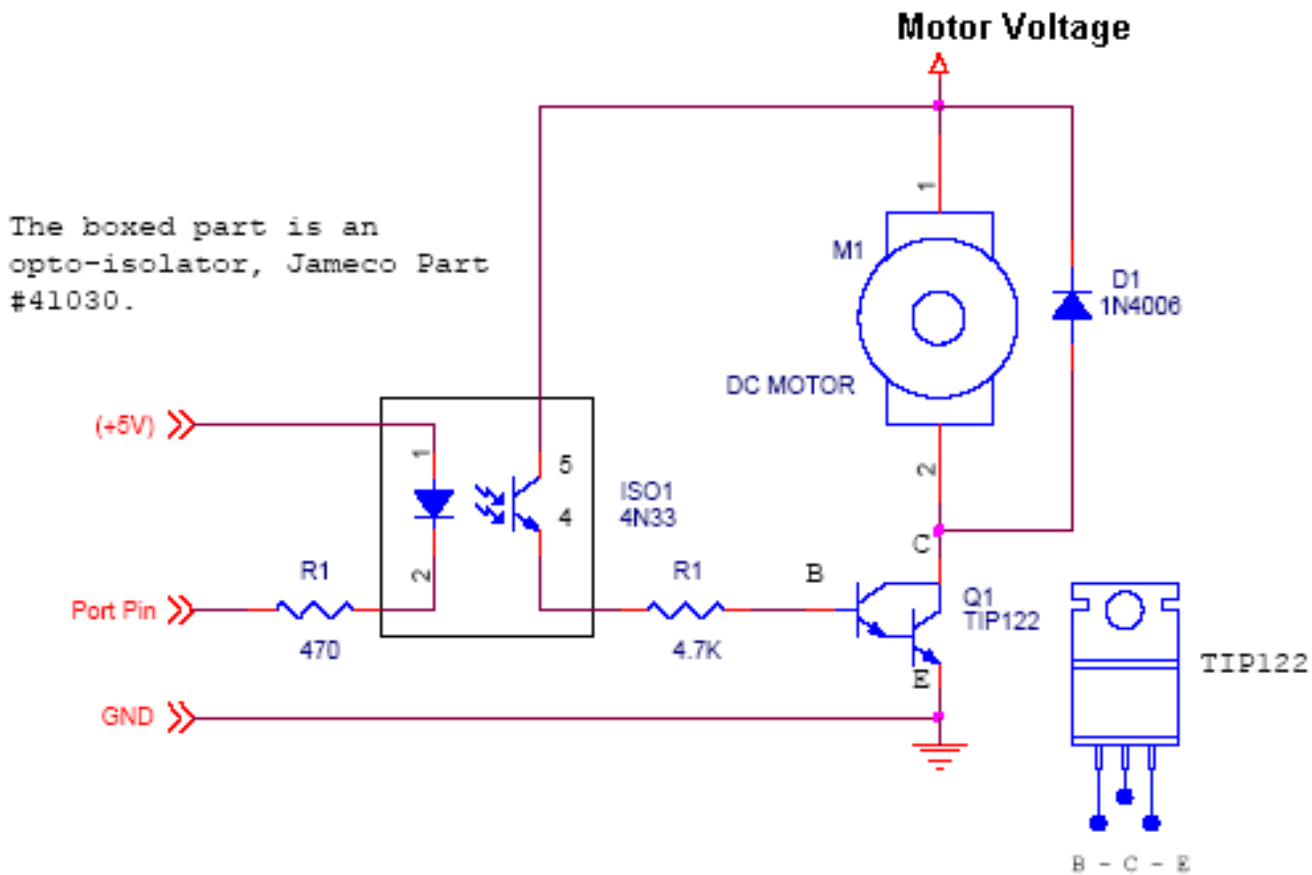
FAIRCHILD SEMICONDUCTOR

TIP41 Series(TIP41/41A/41B/41C)

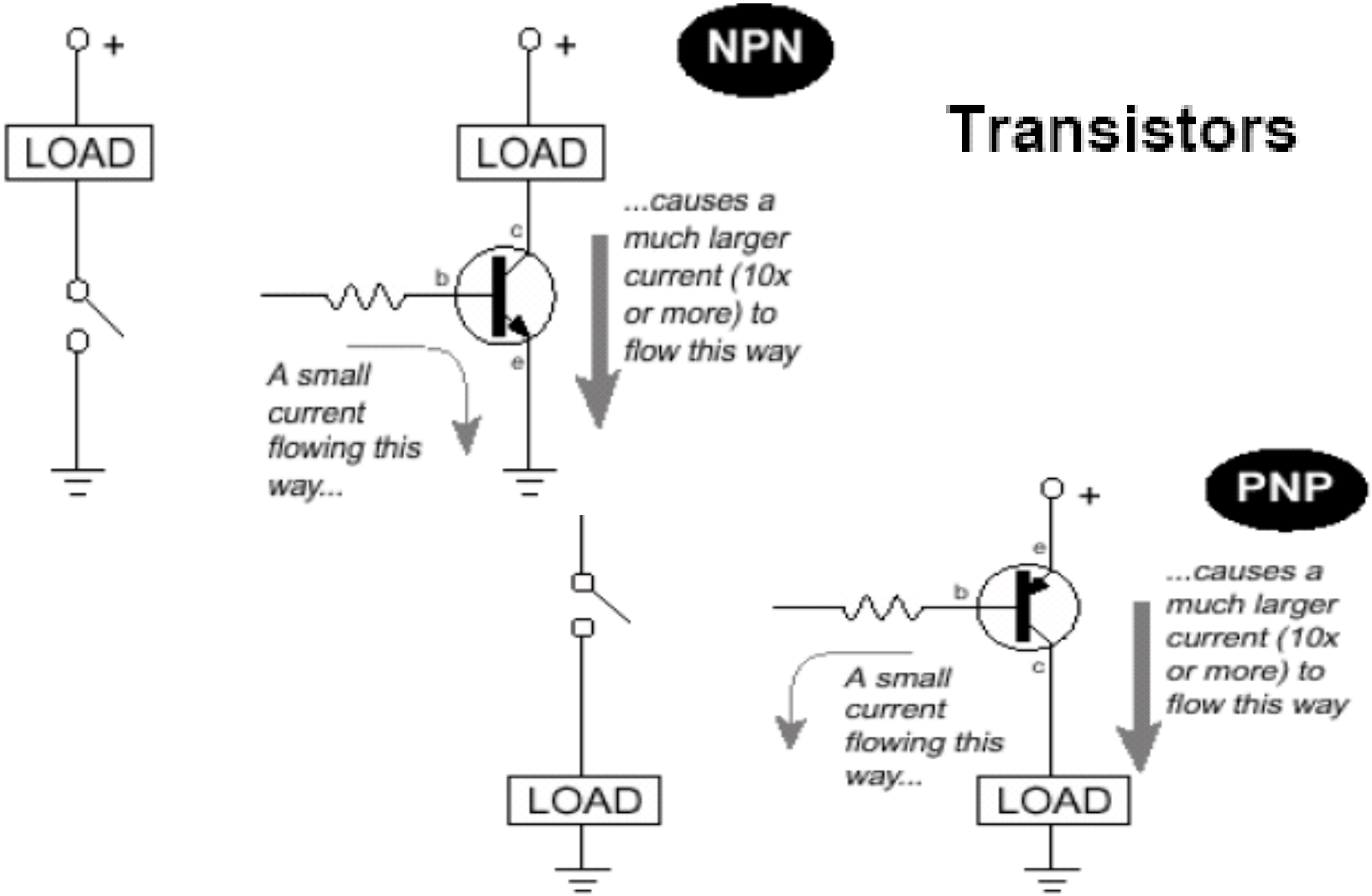
Medium Power Linear Switching Applications



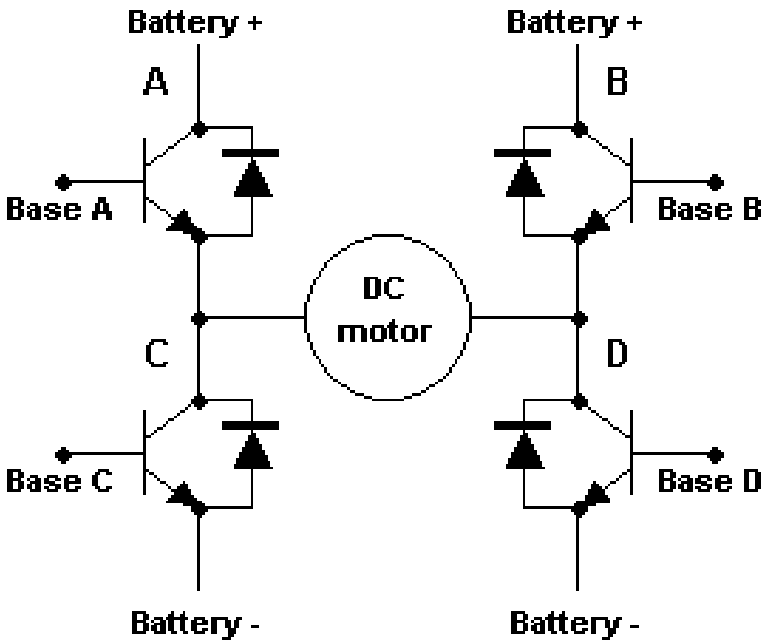
1.Base 2.Collector 3.Emitter



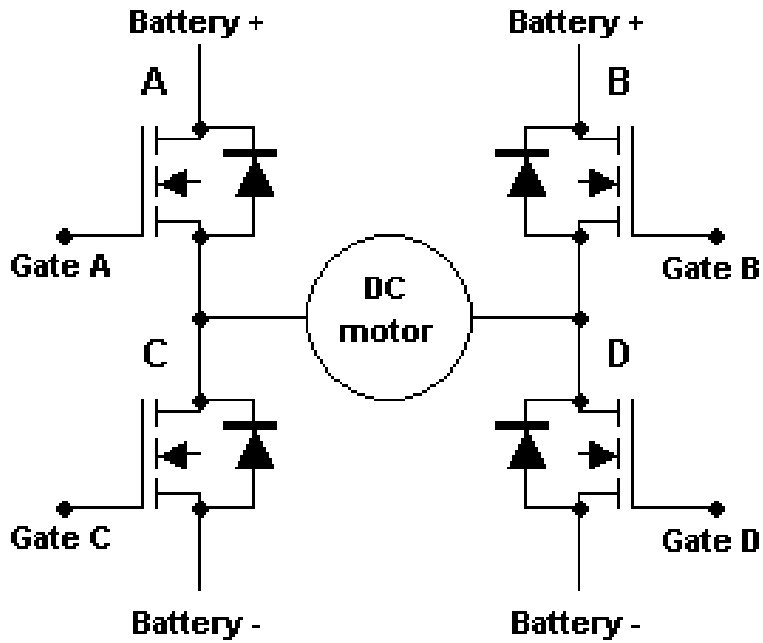
Transistors for Control



Transistor vs. MOSFET



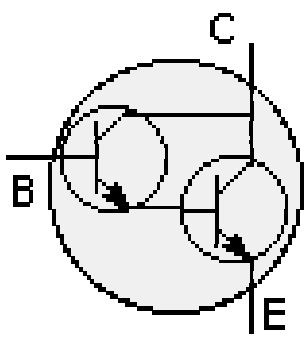
Transistor H-bridge

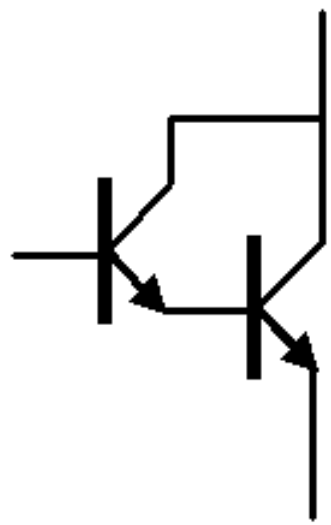


MOSFET H-bridge

Darlington (Transistor)

- Connection of two bipolar transistors in tandem in a single device.
- High gain (or beta)
- Less space
- Invented by Bell Laboratories engineer Sidney Darlington.



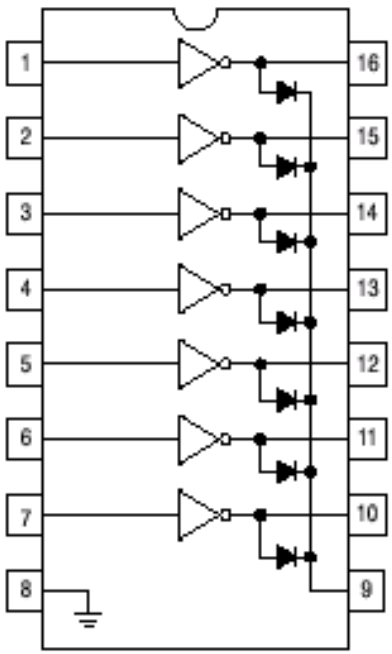


Transistor Array

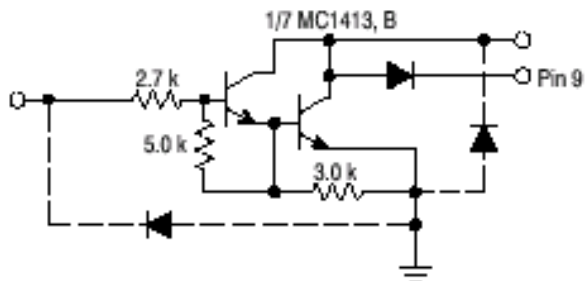
ON Semiconductor®

MC1413, MC1413B, NCV1413B

High Voltage, High Current Darlington Transistor Arrays



PDIP−16
P SUFFIX
CASE 648

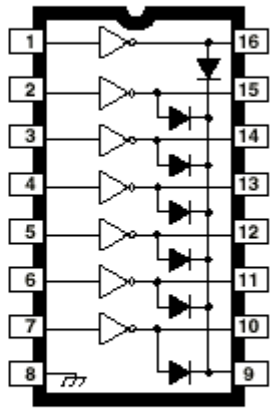


Darlington Array

Allegro 2003 THRU 2024

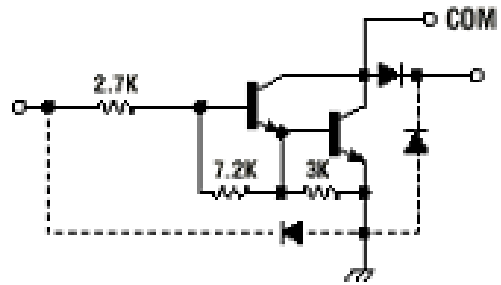
FEATURES

- TTL, DTL, PMOS, or CMOS-Compatible Inputs
- Output Current to 500 mA
- Output Voltage to 95 V
- Transient-Protected Outputs



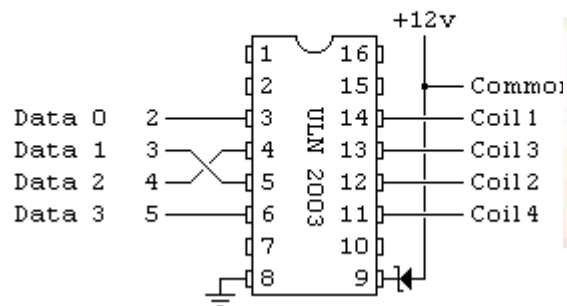
HIGH-VOLTAGE, HIGH-CURRENT DARLINGTON ARRAYS

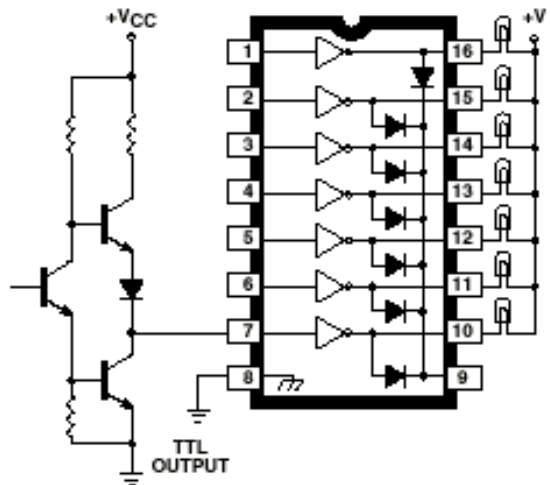
Ideally suited for interfacing between low-level logic circuitry and multiple peripheral power loads



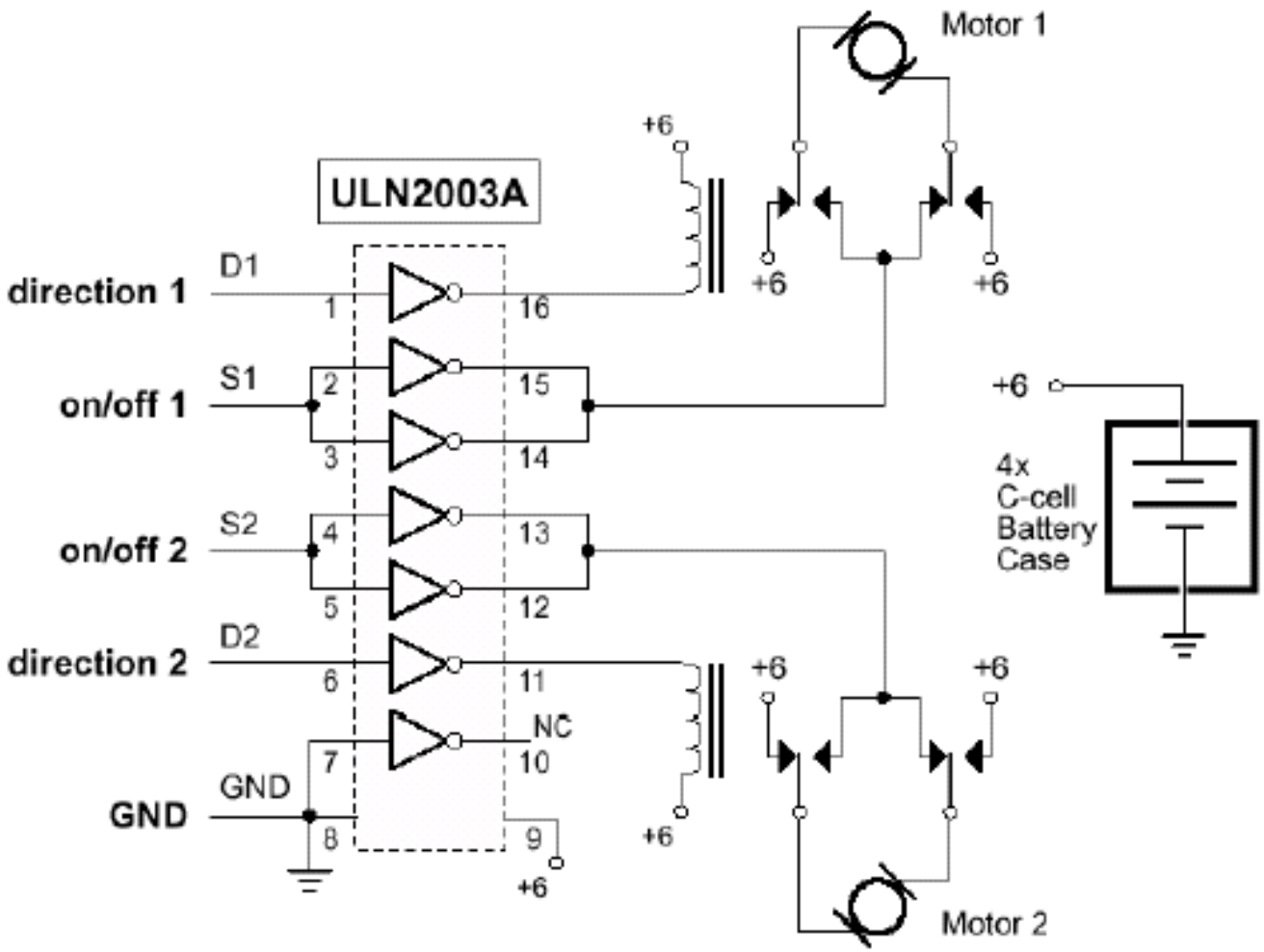
TYPICAL APPLICATIONS

UNIPOLAR STEPPER CONTROL





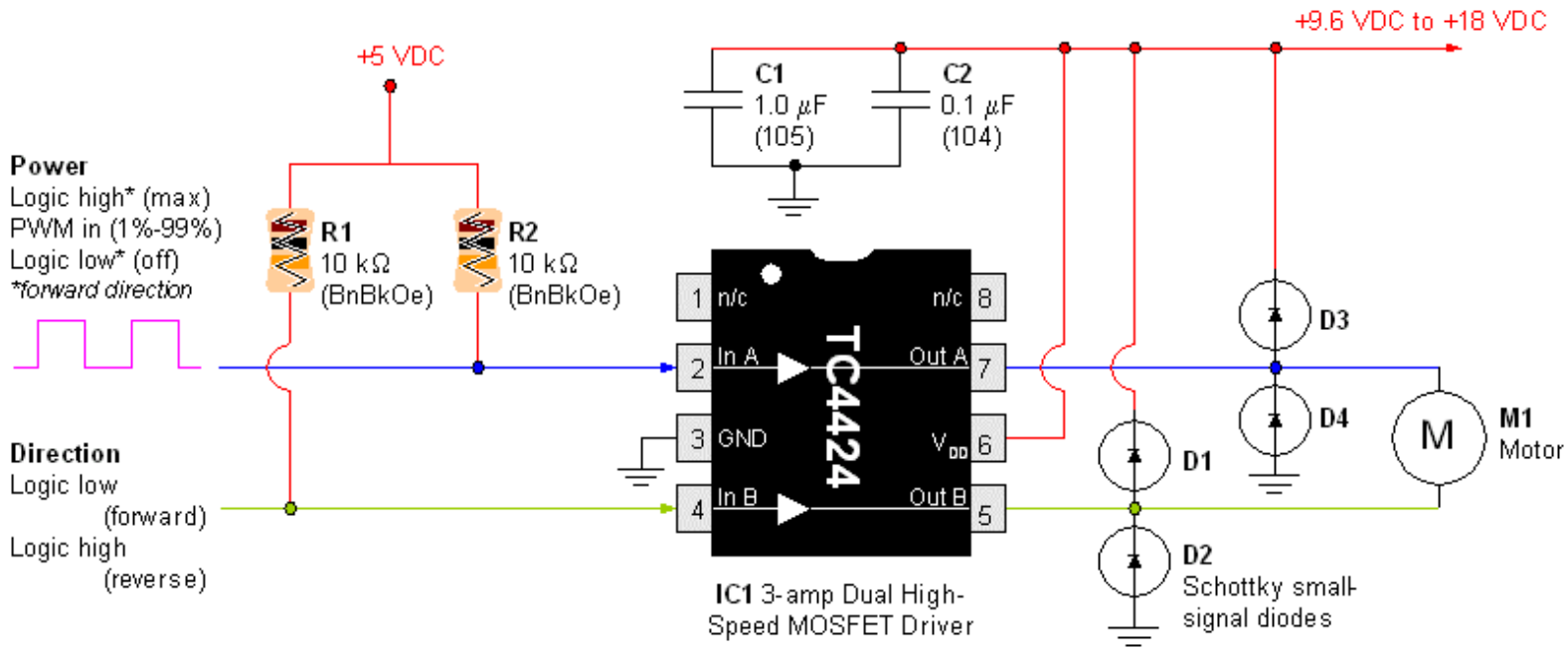
Darlington with DPDT relays



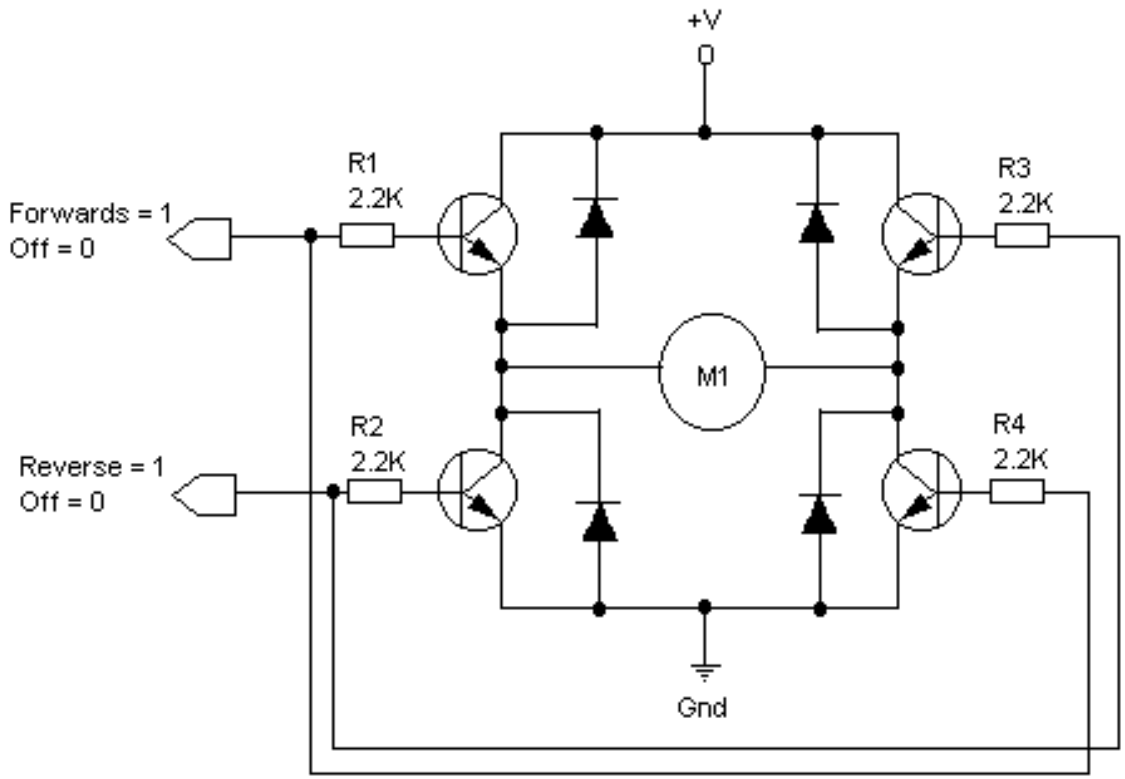
MOSFET for Motor Control

MICROCHIP **TC4423/TC4424/TC4425**

3A Dual High-Speed Power MOSFET Drivers

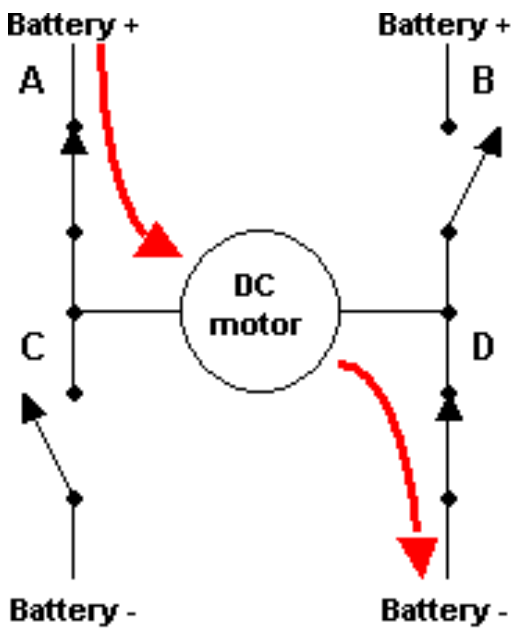


DC Motor H-Bridge Control

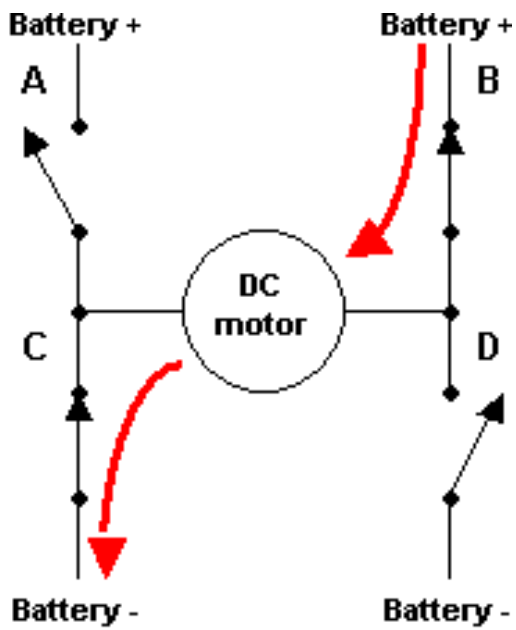


Diode 1N4002
Transistor TIP41 NPN Power Transistor
Resistor 2.2 K 0.25 W

Rotation Control using H-Bridge

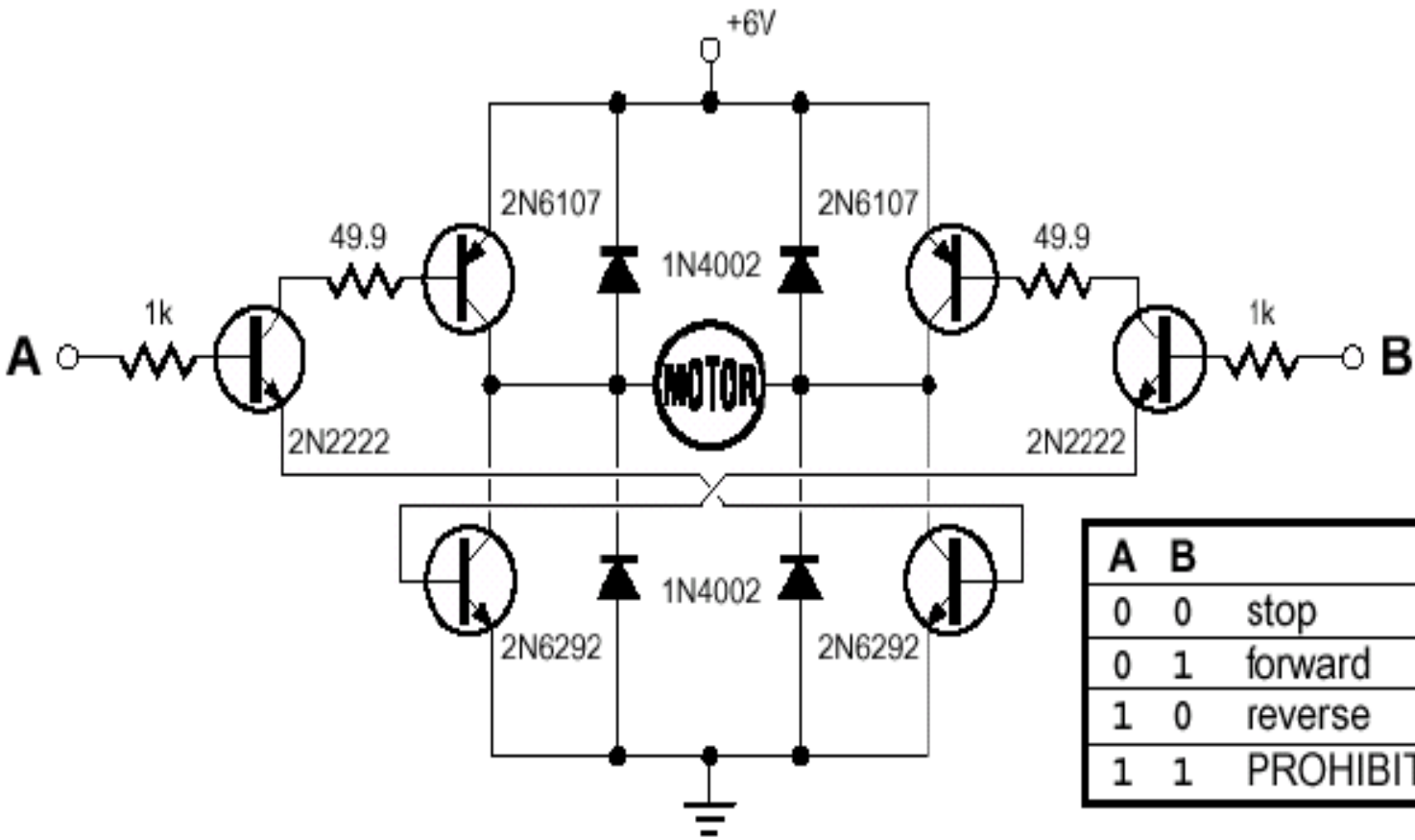


H-bridge CW rotation



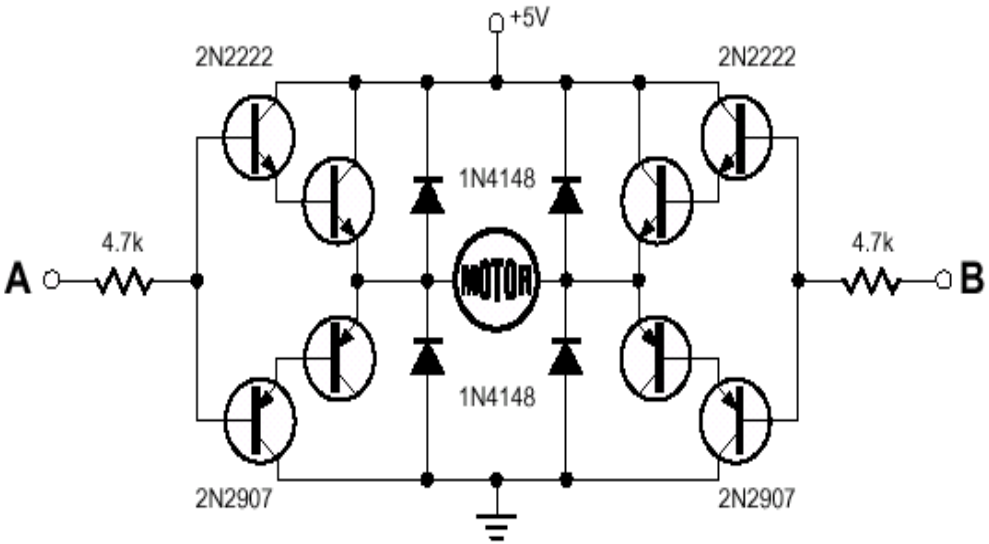
H-bridge CCW rotation

Standard H-Bridge Control

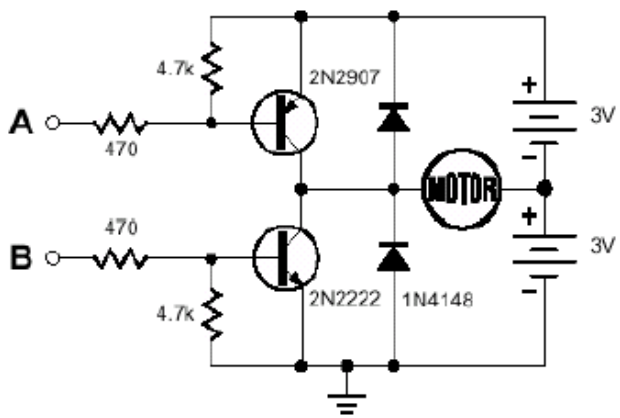


A	B	
0	0	stop
0	1	forward
1	0	reverse
1	1	PROHIBITED

Full/Half H-Bridge



A	B	
0	0	stop
0	1	forward
1	0	reverse
1	1	stop



A	B	
0	0	forward
0	1	PROHIBITED
1	0	stop
1	1	reverse

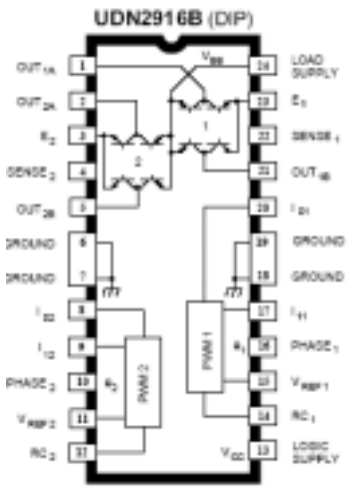
Bridge Motor Driver

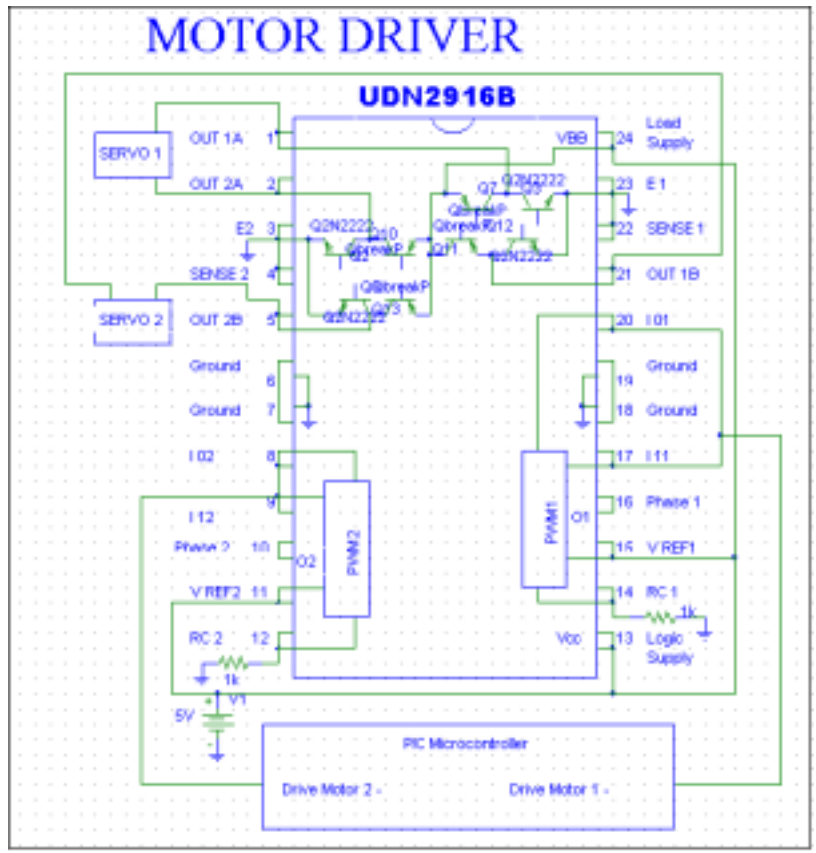
Allegro MicroSystems, Inc.

2916

DUAL FULL-BRIDGE PWM MOTOR DRIVER

a bipolar stepper motor or bidirectionally control two dc motors.

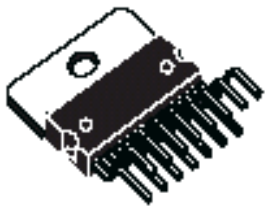




Bridge Driver

L298

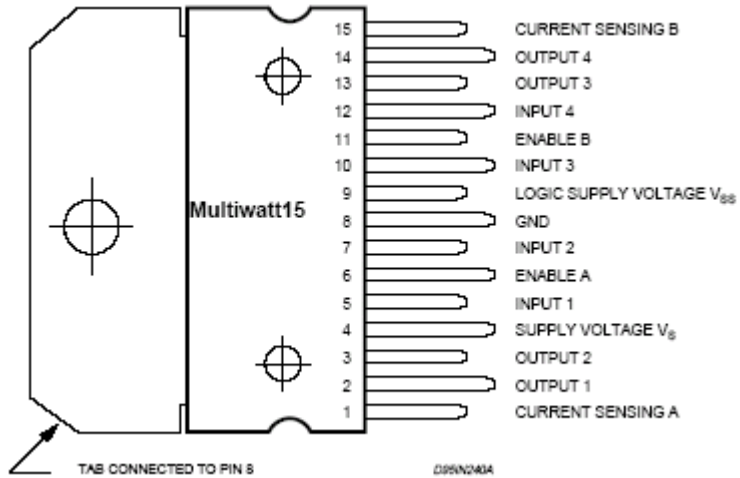
DUAL FULL-BRIDGE DRIVER

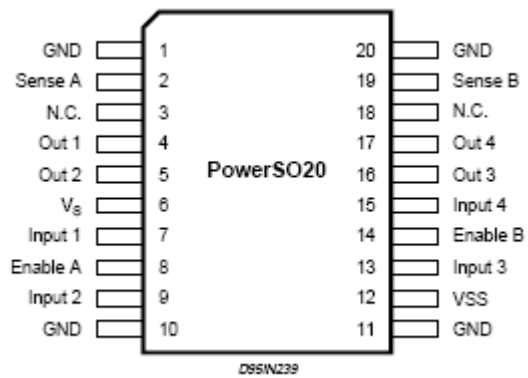


Multiwatt15

PowerSO20

ORDERING NUMBERS : L298N (Multiwatt Vert.)
L298HN (Multiwatt Horiz.)
L298P (PowerSO20)

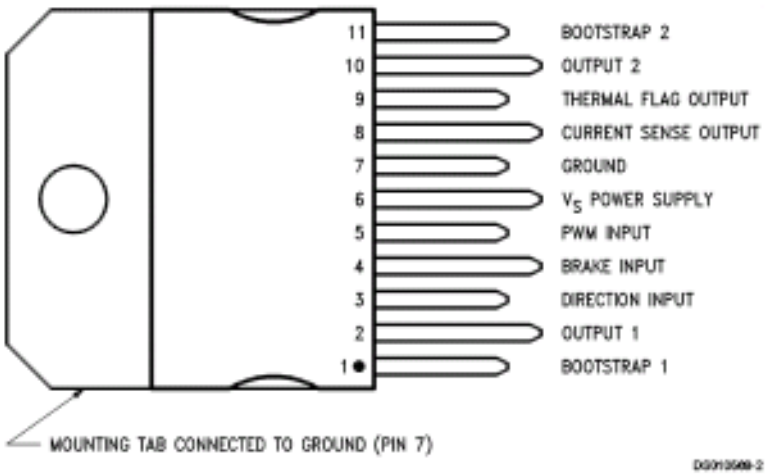




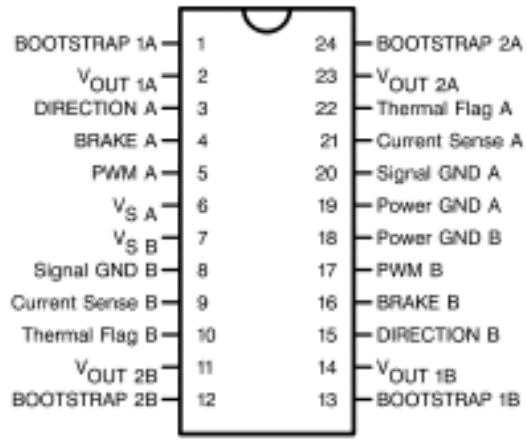
H-Bridge Driver

National Semiconductor

LMD18200
3A, 55V H-Bridge



11-Lead TO-220 Package
Top View
Order Number LMD18200T

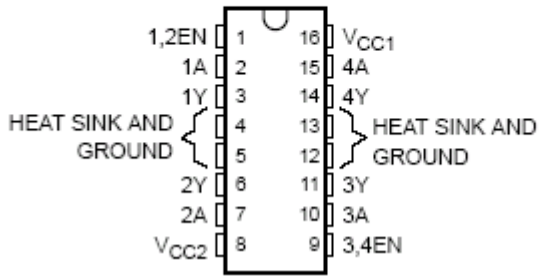


24-Lead Dual-In-Line Package
Top View
Order Number LMD18200-2D-QV
5962-9232501VXA
LMD18200-2D/883
5962-9232501MXA

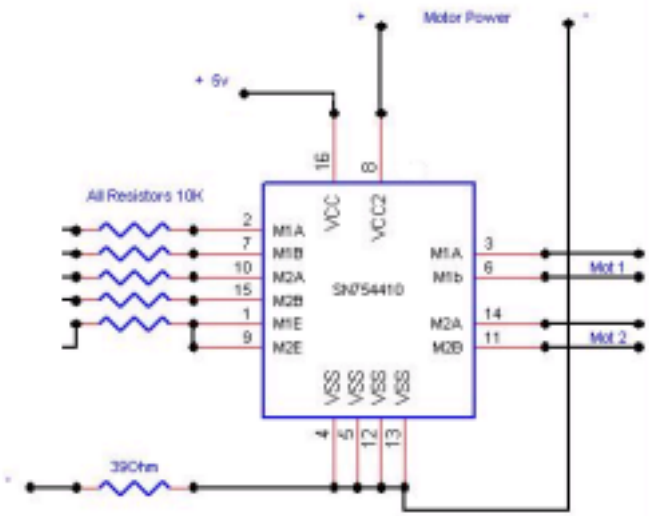
Bridge Driver

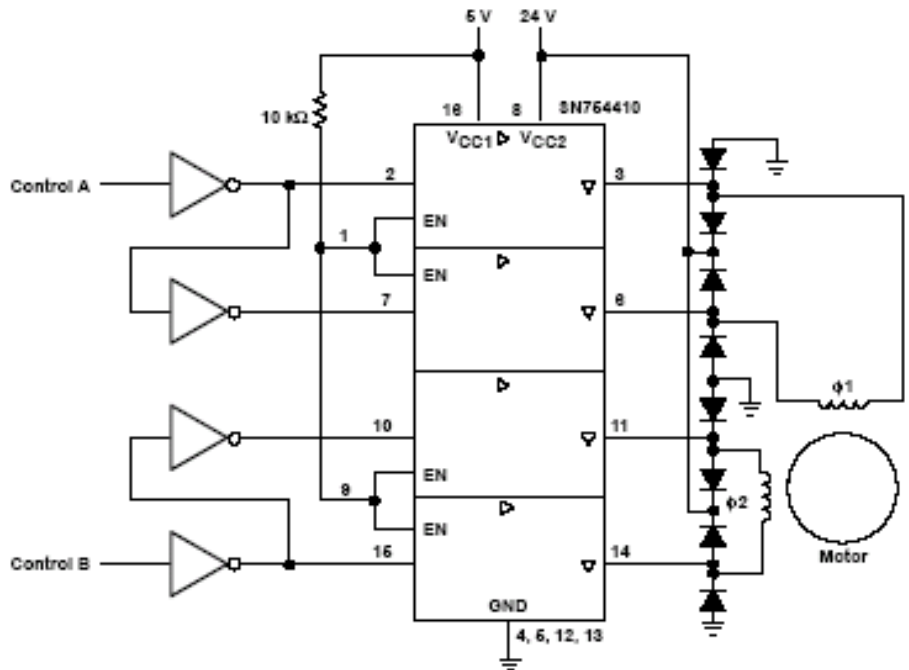
TEXAS INSTRUMENTS

SN754410
QUADRUPLE HALF-H DRIVER

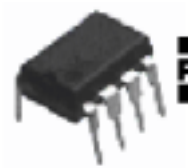


- 1-A Output-Current Capability Per Driver
- Applications Include Half-H and Full-H Solenoid Drivers and Motor Drivers
- Designed for Positive-Supply Applications
- Wide Supply-Voltage Range of 4.5 V to 36 V

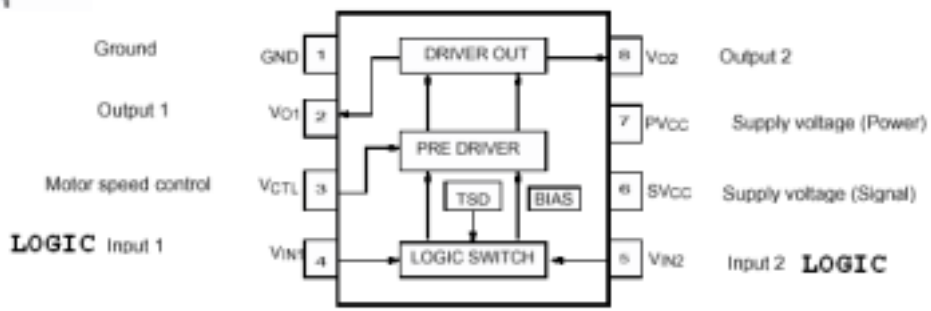




DC Motor Driver



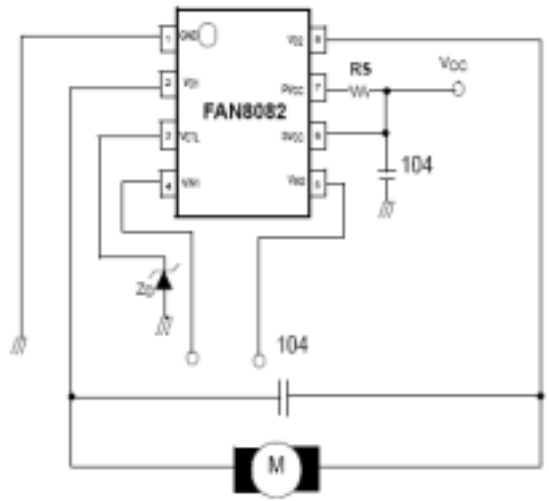
FAIRCHILD **FAN8082** **Bi-directional DC Motor Driver**



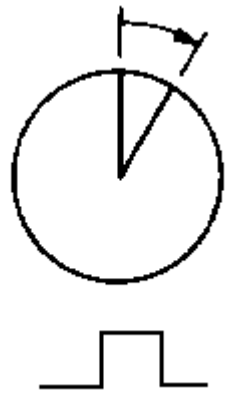
Parameter	Symbol	Operating voltage range
Operating supply voltage	SV_{CC},PV_{CC}	7 ~ 18

LOGIC INPUT & OUTPUT TABLE

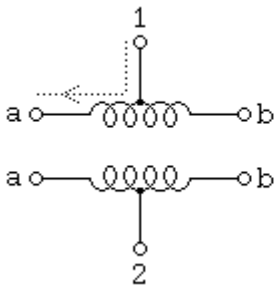
Input		Output		Motor
Pin #4	Pin #5	Pin #2	Pin #8	
Low	Low	*Low	*Low	Brake
High	Low	High	Low	Forward
Low	High	Low	High	Reverse
High	High	*Low	*Low	Brake

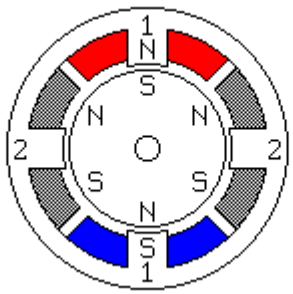


Stepper Motors

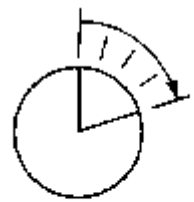


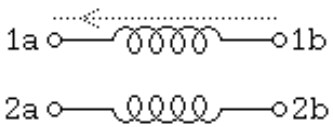
STEPPER MOTORS

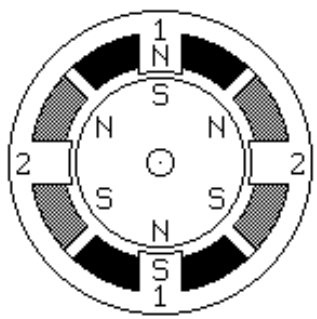




2-phase
Unipolar (Single Polarity)

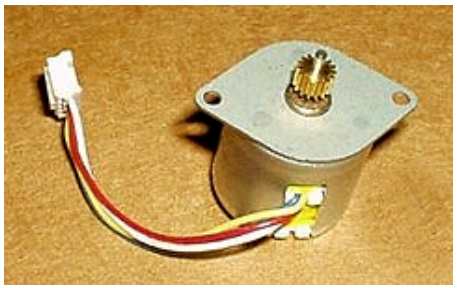


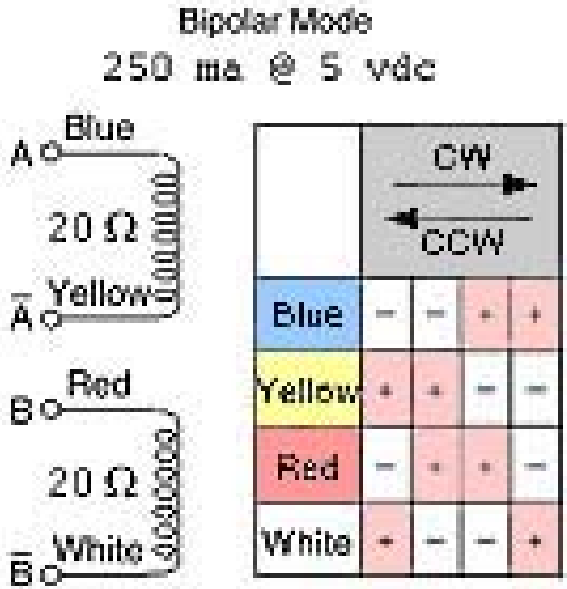




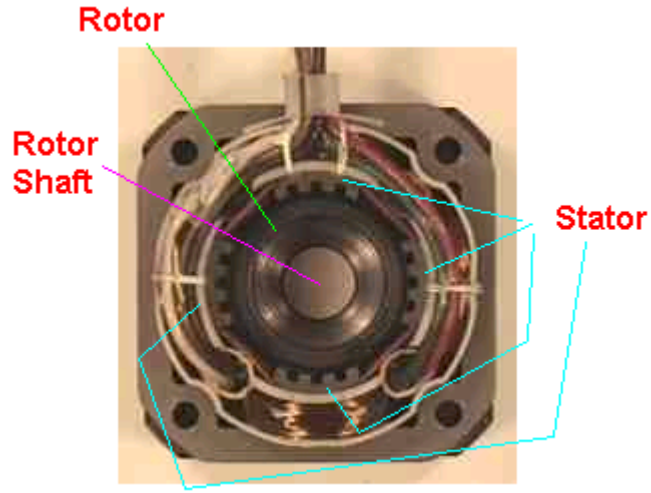
2-Phase
Bipolar

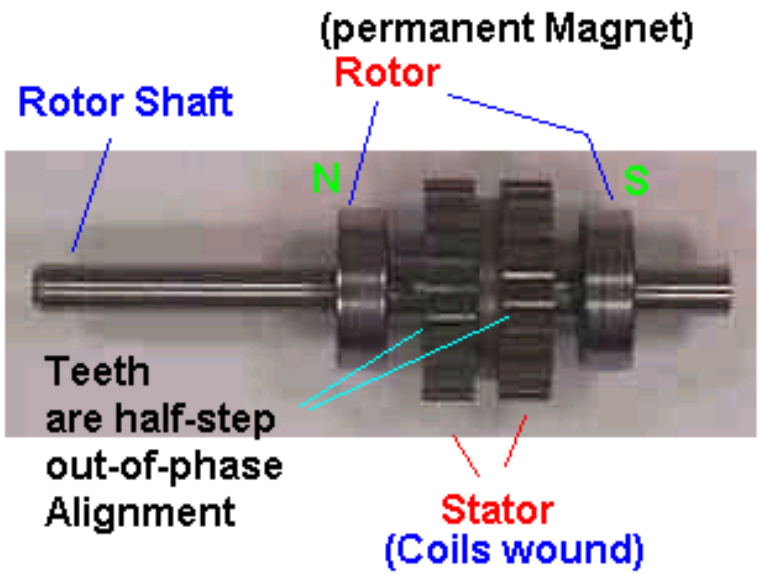
Stepper Motors

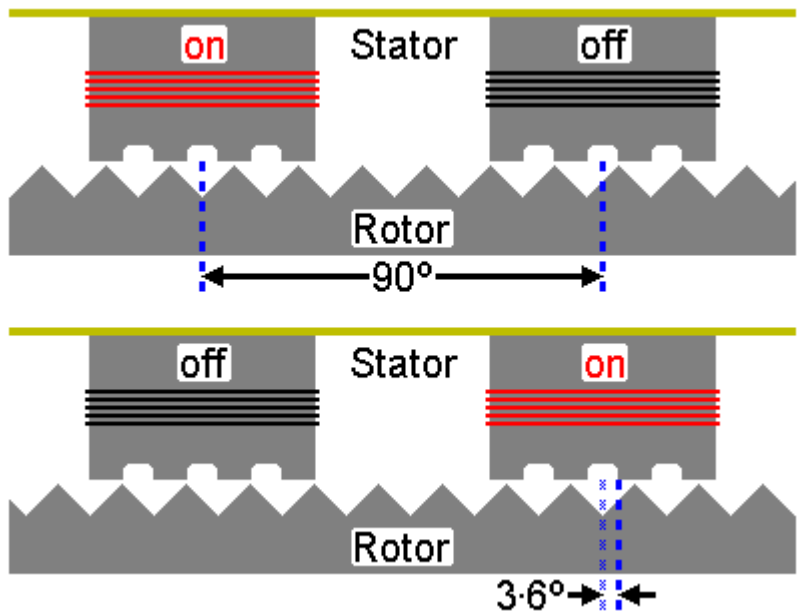




Stepper Motor Structure

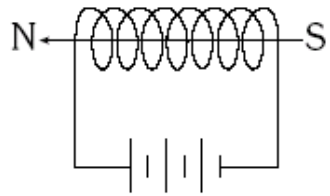


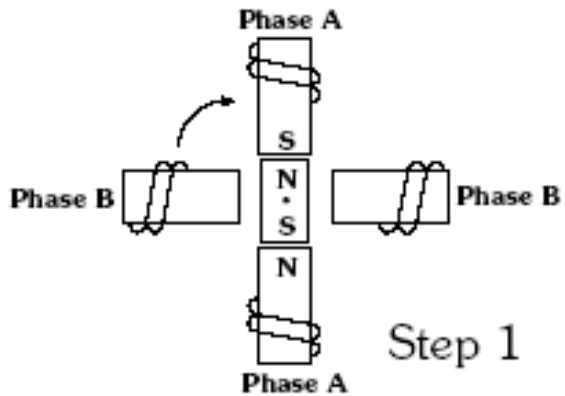


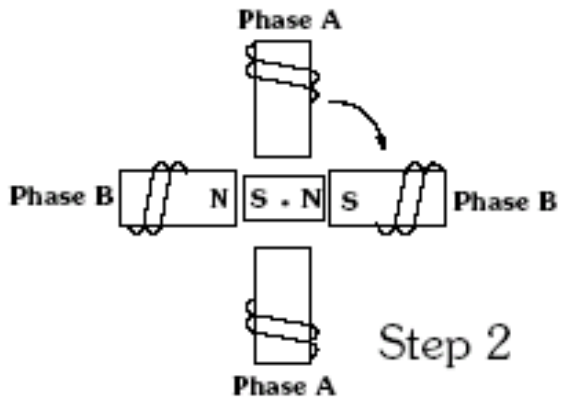


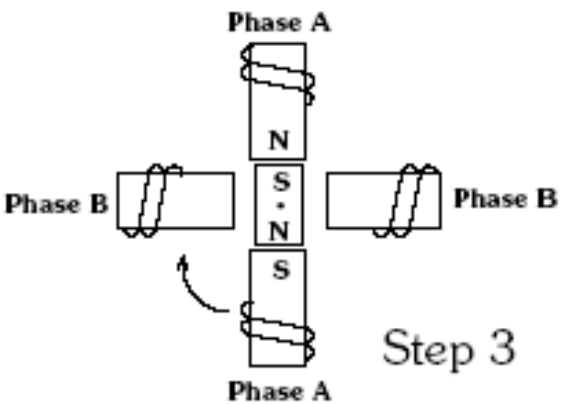
Stepper Motor -Theory

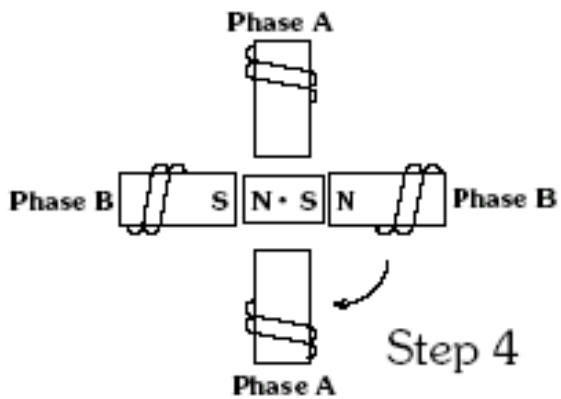
- **Magnetic Field Created by Energized Coil**
- **Steps for "One phase On" for two phase stepping motor**





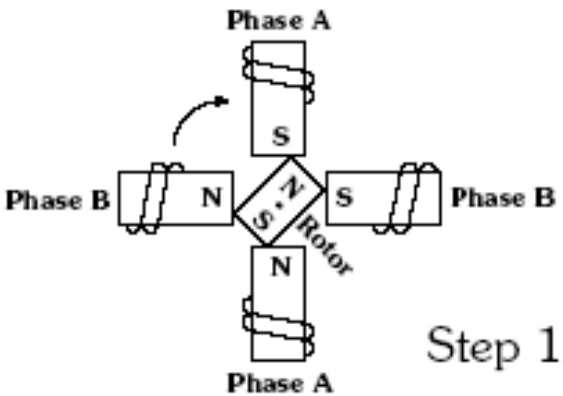


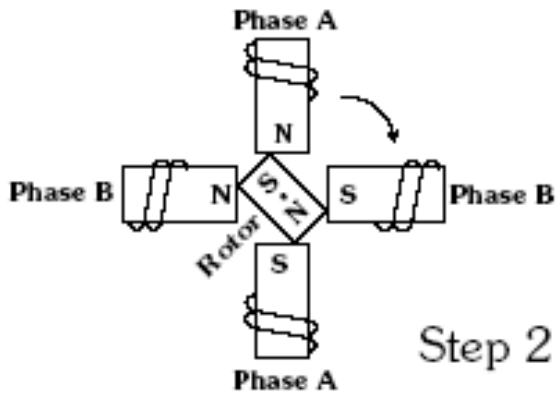


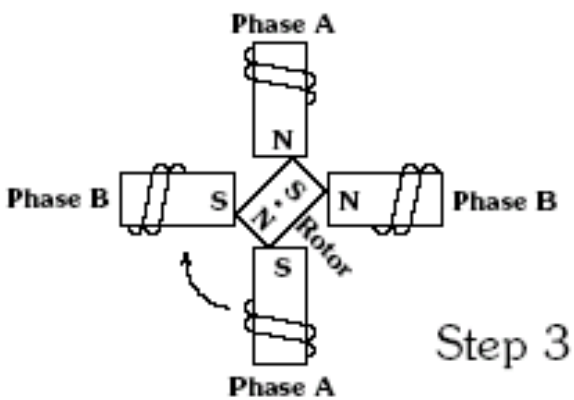


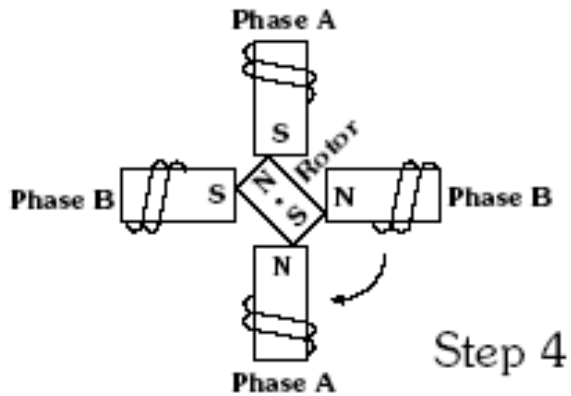
Stepper Motor Theory

- **"Two Phase On" for a 2-phase stepper**

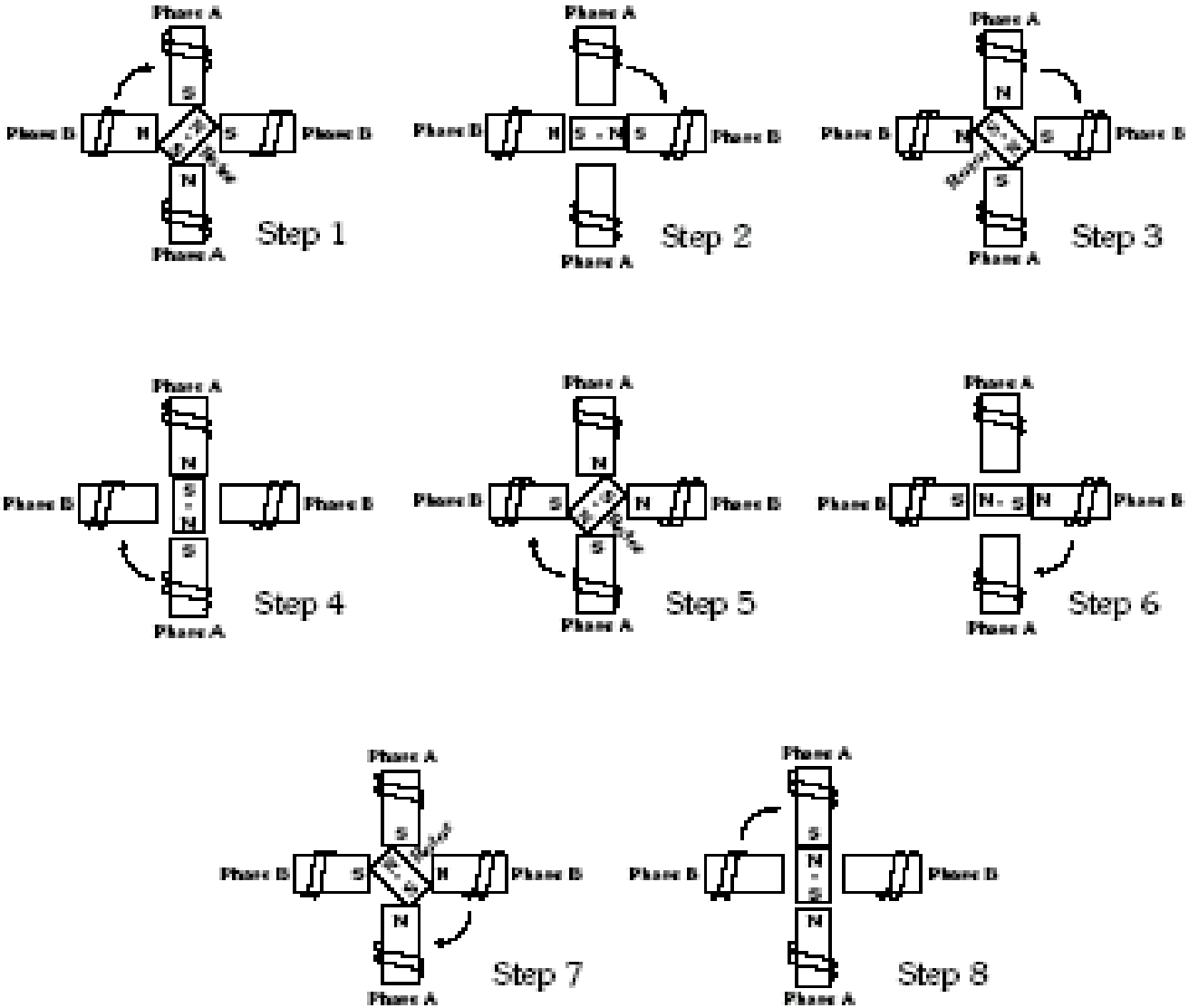




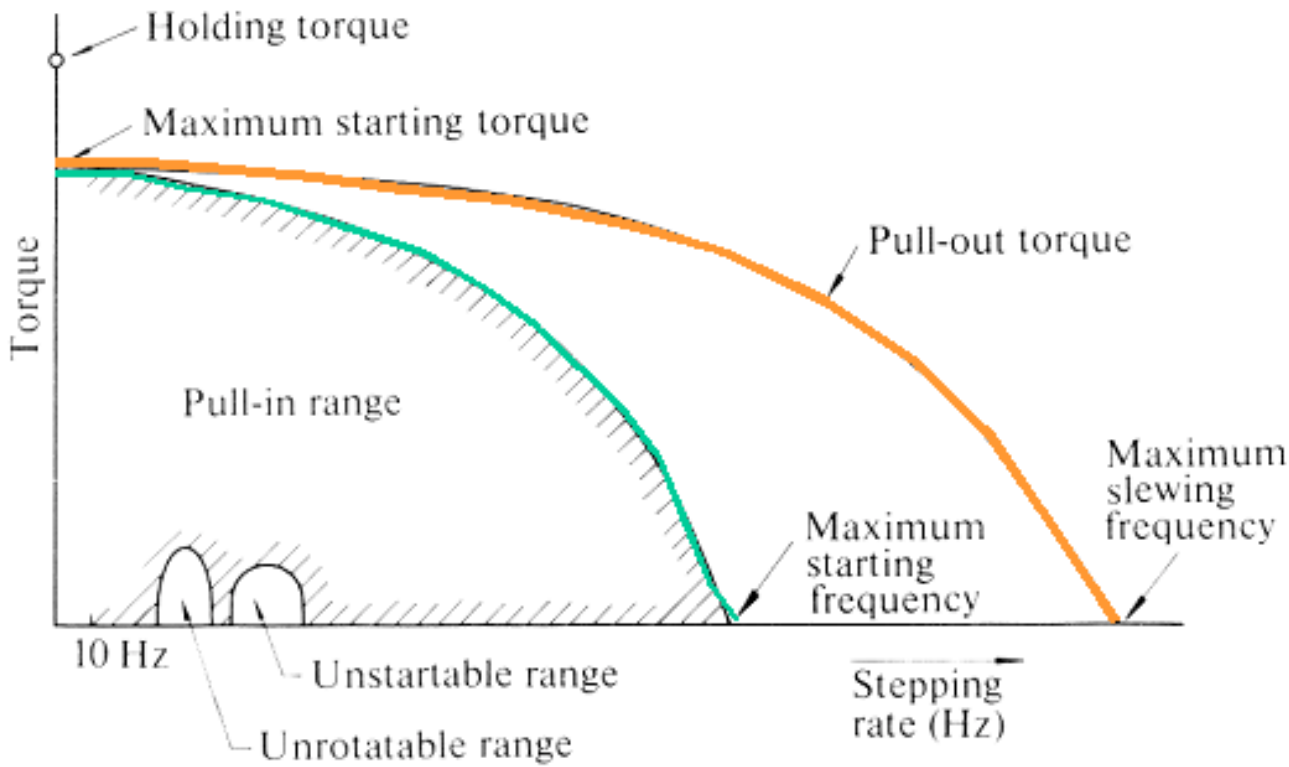




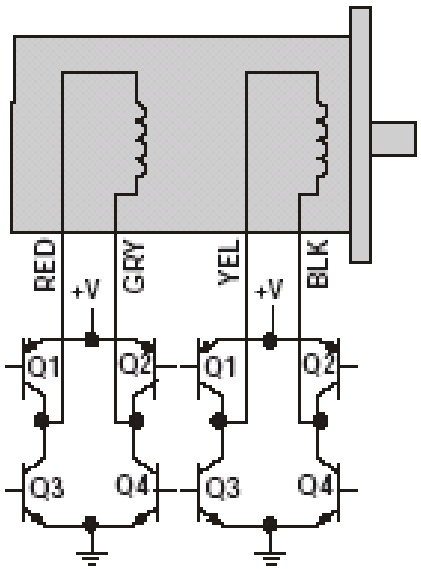
Half-Stepping

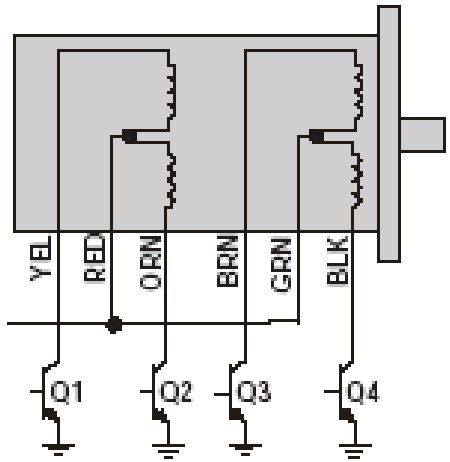


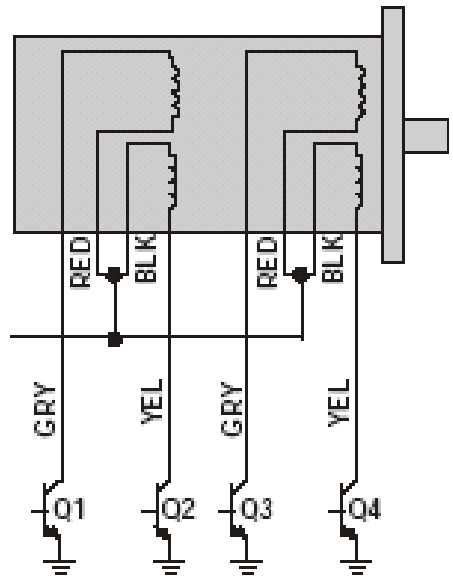
Stepper Motor – Speed vs. Torque



Sequence for Unipolar and Bipolar







BIPOLAR

CW ROTATION

Step	Q_1-Q_4	Q_2-Q_3	Q_5-Q_8	Q_6-Q_7
1	ON	OFF	ON	OFF
2	ON	OFF	OFF	ON
3	OFF	ON	OFF	ON
4	OFF	ON	ON	OFF
1	ON	OFF	ON	OFF

CCW ROTATION

Normal
4-Step Sequence

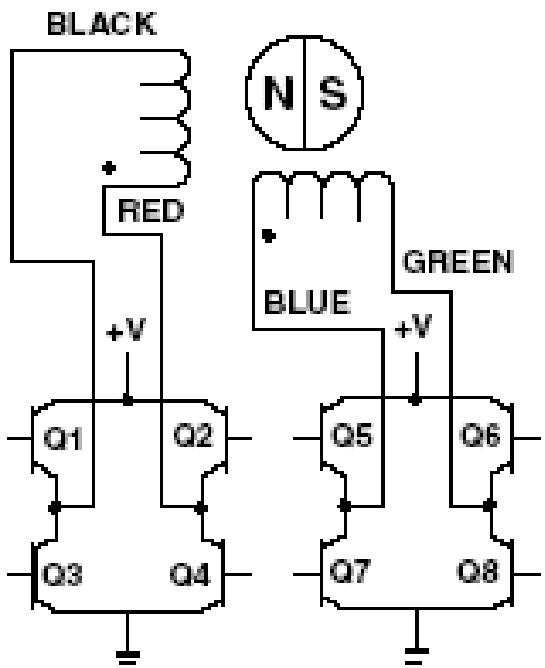
UNIPOLAR

CW ROTATION

Step	Q_1	Q_2	Q_3	Q_4
1	ON	OFF	ON	OFF
2	ON	OFF	OFF	ON
3	OFF	ON	OFF	ON
4	OFF	ON	ON	OFF
1	ON	OFF	ON	OFF

CCW ROTATION

Bipolar Stepper Control Sequence

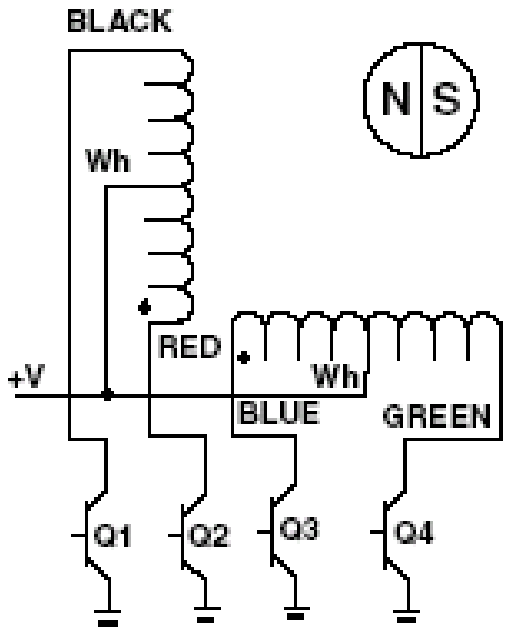


CW Rotation ↓

Bipolar Step	Q2-Q3	Q1-Q4	Q6-Q7	Q5-Q8
1	ON	OFF	ON	OFF
2	OFF	ON	ON	OFF
3	OFF	ON	OFF	ON
4	ON	OFF	OFF	ON
1	ON	OFF	ON	OFF

↑ CCW Rotation

Unipolar Stepper Motor Sequence



CW Rotation ↓

Unipolar Step	Q1	Q2	Q3	Q4
1	ON	OFF	ON	OFF
2	OFF	ON	ON	OFF
3	OFF	ON	OFF	ON
4	ON	OFF	OFF	ON
1	ON	OFF	ON	OFF

CCW Rotation ↑

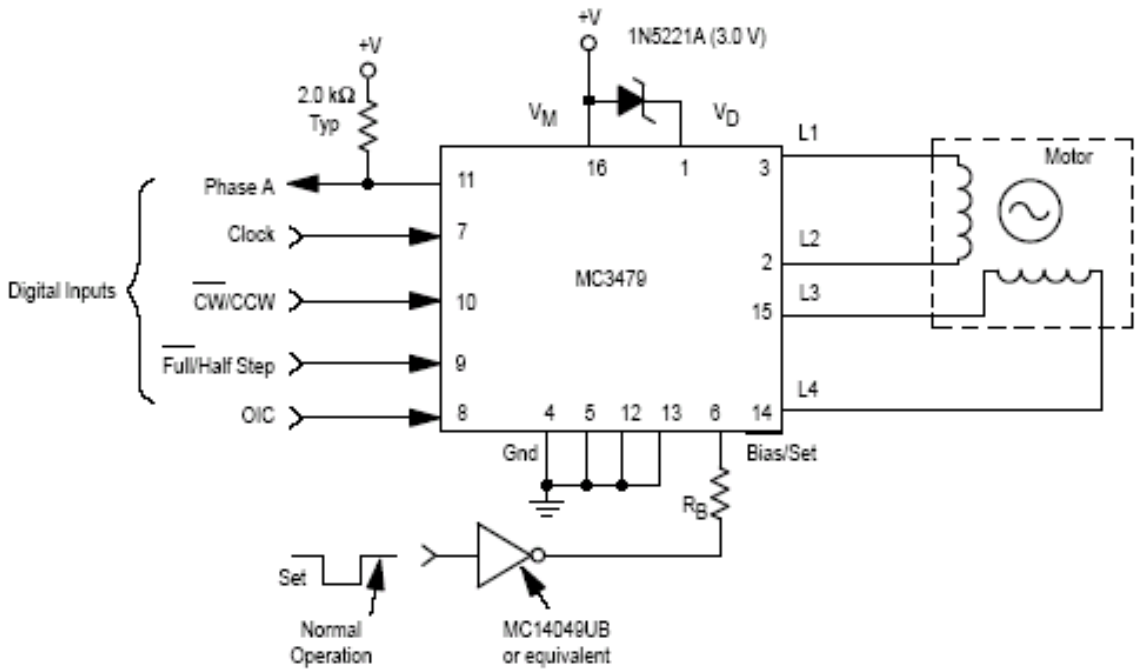
Bipolar Stepper Motor Driver

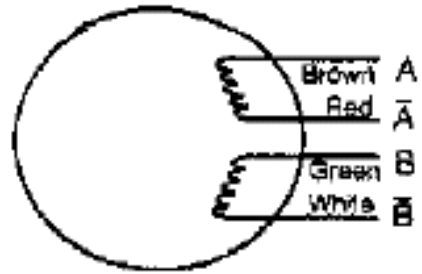
MOTOROLA **MC3479**

Stepper Motor Driver

two–phase stepper motor in the bipolar mode.

- Single Supply Operation: 7.2 to 16.5 V
- 350 mA/Coil Drive Capability





Step	A	B	Ā	B̄
1	+	+	-	-
2	-	+	+	-
3	-	-	+	+
4	+	-	-	+
5	+	+	-	-

Bipolar Driver

Allegro MicroSystems, Inc.

2916

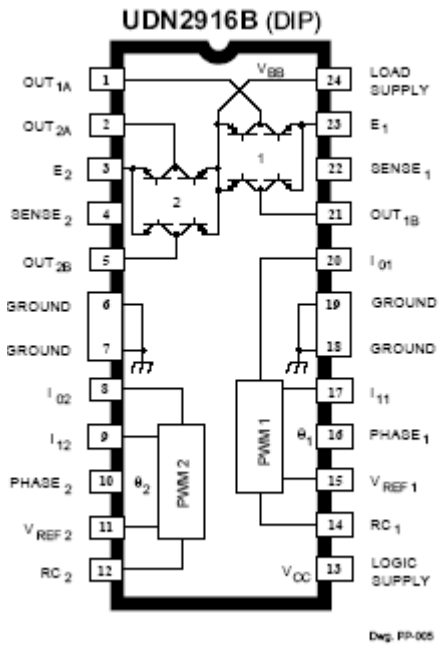
Part Number	Package
UDN2916B	24-Pin DIP
UDN2916EB	44-Lead PLCC
UDN2916LB	24-Lead SOIC

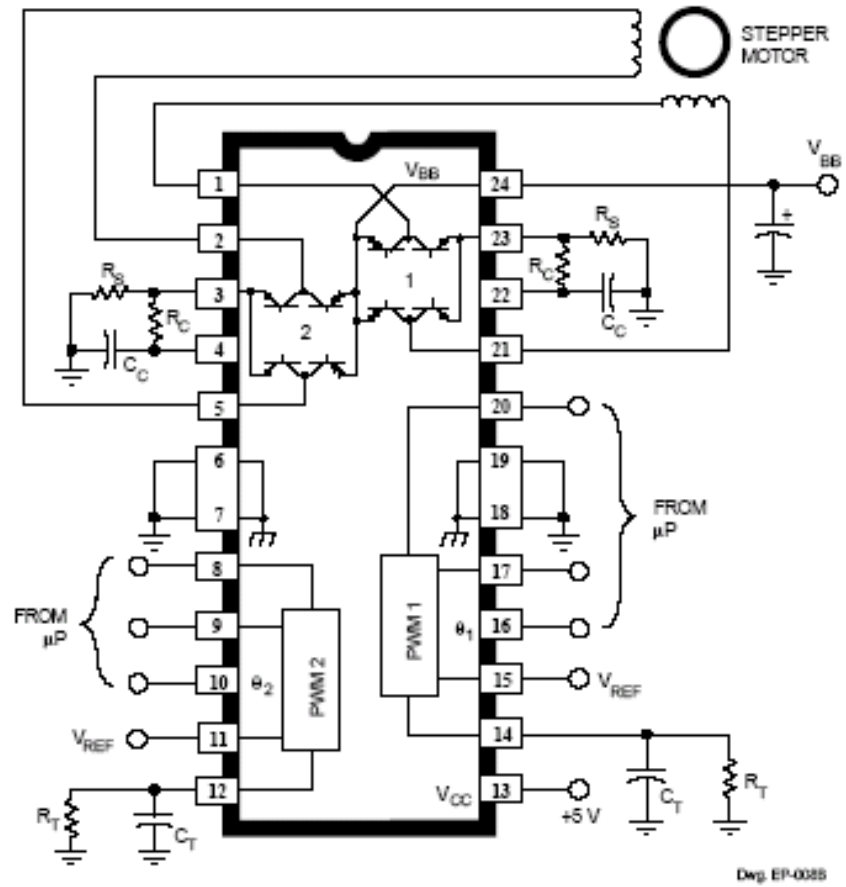
FEATURES

- 750 mA Continuous Output Current
- 45 V Output Sustaining Voltage

DUAL FULL-BRIDGE PWM MOTOR DRIVER

For BIPOLAR STEPPER /DC





Unipolar Driver

Allegro MicroSystems, Inc.

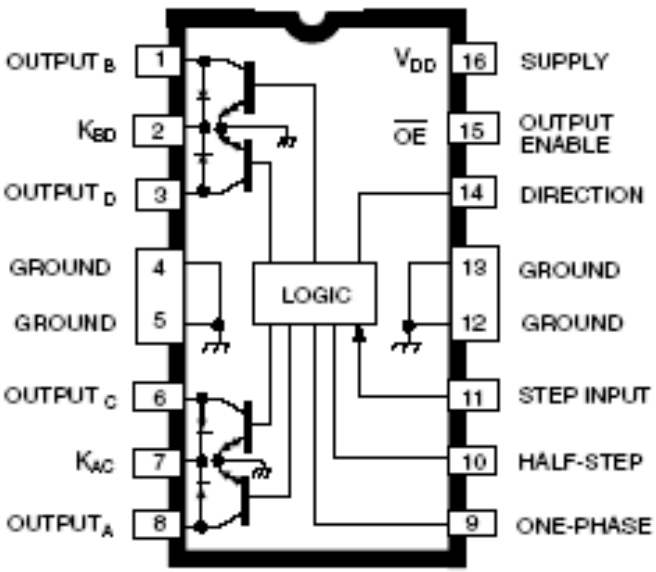
5804

UCN5804B

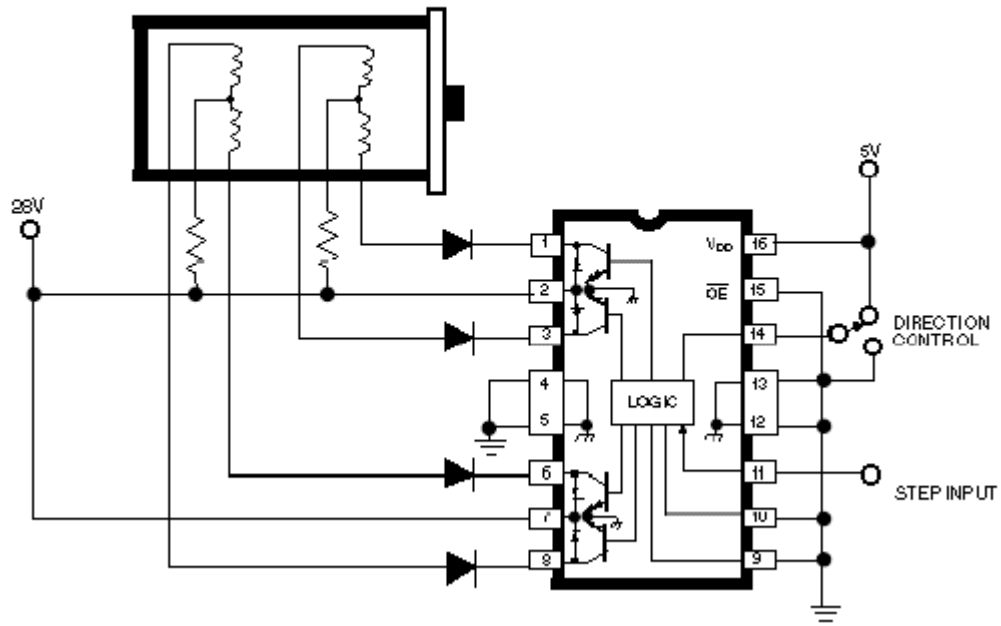
UNIPOLAR STEPPER-MOTOR DRIVER

FEATURES

- 1.5 A Maximum Output Current
- 35 V Output Sustaining Voltage



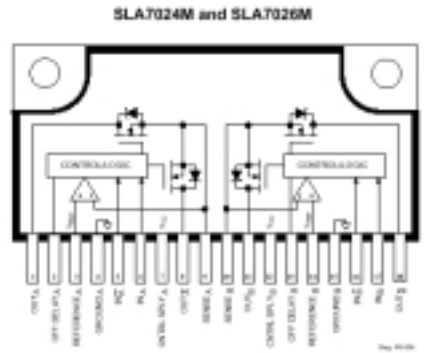
TYPICAL APPLICATION
L/R Stepper-Motor Drive

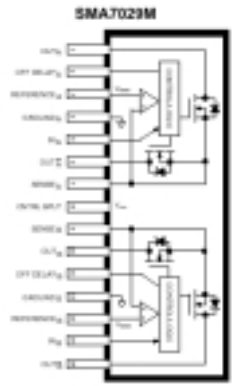


Unipolar Stepper Driver

SLA7024M, SLA7026M, AND SMA7029M

HIGH-CURRENT PWM, UNIPOLAR STEPPER MOTOR CONTROLLER/DRIVERS

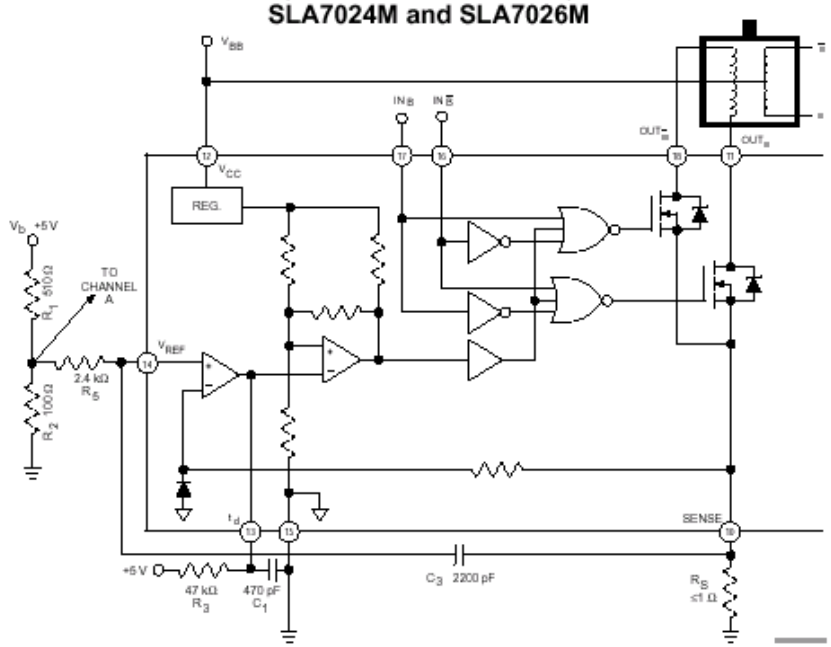




2-PHASE (FULL STEP) OPERATION for SLA7024M and SLA7026M

Sequence	0	1	2	3	0
Input A	H	L	L	H	H
Input $\overline{A}$	L	H	H	L	L
Input B	H	H	L	L	H
Input $\overline{B}$	L	L	H	H	L
Outputs ON	AB	$\overline{A}$ B	$\overline{AB}$	A $\overline{B}$	AB

TYPICAL STEPPER MOTOR APPLICATIONS
(Half of Each Device Shown)
SLA7024M and SLA7026M



Motors

JAMECO

12VDC Bipolar Stepper Motor

3.6° / Step

- No. of phases: 2
- Detent torque: 80 g-cm
- Holding torque: 600 g-cm
- Phase resistance: 25Ω
- Phase inductance: 31mH
- Current: 480mA
- Mounting hole size: 0.11"
- Shaft size: 0.43"L x 0.197"Dia.
- Motor size: 1.66"Dia. x 1.31"H

Part No.	Mfr. Cross Ref. No.	1	10	50
105881	SM4203	$5.99	$5.59	$4.95

12VDC Unipolar Stepper Motor

3.6° / Step

- No. of phases: 4
- Detent torque: 80 g-cm
- Holding torque: 600 g-cm
- Phase resistance: 75Ω
- Phase inductance: 39mH
- Current: 150mA
- Mounting hole size: 0.11"
- Shaft size: 0.43"L x 0.197"Dia.
- Motor size: 1.66"Dia. x 1.28"H

Part No.	Mfr. Cross Ref. No.	1	10	50
105890	SM4200	$8.79	$7.85	$6.99

12VDC Unipolar Stepper Motor

.09° / Step

- No. of phases: 4
- Detent torque: 400 g-cm
- Holding torque: 400 g-cm
- Phase resistance: 200Ω
- Phase inductance: 49.5mH
- Current: 60mA
- Mounting hole size: 0.14"
- Shaft size: 0.36"L x 0.194"Dia.
- Motor size: 1.18"Dia. x 0.68"H

Part No.	Mfr. Cross Ref. No.	1	10	50
173180	30BYJ02AH	$11.49	$10.35	$9.35

Bipolar and Unipolar Stepper Motors

Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5

Fig. 6

Fig. 7

Fig. 8

Part Number	Mfr. Cross Ref. No.	Fig.	Step Angle	No. of Phases	Drive System	Volt. (VDC)	Phase Resis. (Ohms)	Curr. (mA)	Phase Inductance (mH)	Detent Torque (g-cm)	Holding Torque (g-cm)	Mounting Hole Space Diagonal (in.)	Mounting Holes (in.)	Shaft Dia. (in.)	Shaft Length (in.)	Motor Dia. (in.)	Motor Height (in.)	Pricing		
																		1	10	50
117954	LB82773-M1	1	7.5°	2	Bipolar	5	6	800	7	100	1080	2.60	1.95	0.250	0.75	2.25	1.00	$3.79	$2.99	$2.25
163395	5017-935[1]	2	0.9°	2	Bipolar	8.4	30	280	25	36	791	1.73	0.15	0.155	0.29	1.64	1.20	4.95	3.75	2.65
163408	4017-806[1]	2	1.8°	2	Bipolar	9.2	38	240	52	36	664	1.73	0.15	0.155	0.23	1.66	1.25	2.49	1.89	1.35
105881	SM4203[2/3]	3	3.6°	2	Bipolar	12	25	480	31	80	600	1.73	0.11	0.197	0.43	1.66	1.31	5.99	5.59	4.95
164056	M82101-P1	1	7.5°	3	Unipolar	5	20	255	5	9	94	1.4	0.13	0.078	0.35	1.00	0.46	1.85	1.69	1.55
151861	C42M048A04	4	7.5°	4	Unipolar	5	9	550	10	90	750	1.94	0.13	0.117	0.40	1.65	0.83	5.59	5.05	4.55
171601	PF35T48L4[4]	1	3.6°	4	Unipolar	7	20	350	9	40	680	1.68	0.14	0.078	0.47	1.38	0.58	4.39	3.49	2.65
166705	PM42S-096	1	3.8°	4	Unipolar	12	84	140	16	60	450	1.95	0.13	0.117	0.40	1.66	1.64	3.95	2.95	2.15
105890	SM4200[3]	3	3.6°	4	Unipolar	12	75	150	39	80	600	1.73	0.11	0.197	0.43	1.66	1.28	8.79	7.85	6.99
213321	35BY48-27	7	7.5°	4	Unipolar	12	15	800	68	90	460	1.96	0.13	0.078	0.25	1.38	8.30	14.95	13.49	12.29
173180	30BY102AH[5]	6	.09°	4	Unipolar	12	200	60	49.5	400	400	1.42	0.14	0.194	0.36	1.18	0.68	11.49	10.35	9.35
192794	PM425048[6]	5	7.5°	4	Unipolar	24	45	500	17.5	39	570	1.97	0.09	0.117	0.33	1.66	0.54	4.95	3.75	2.65
210382	5620	1	7.5°	4	Unipolar	24	100	436	60	40	380	1.67	0.13	0.078	0.40	1.38	0.58	5.95	5.49	4.95
210391	STP42N1963	8	3.75°	4	Unipolar	24	110	436	60	60	600	1.95	0.13	0.118	0.42	1.65	0.54	6.95	6.25	5.59

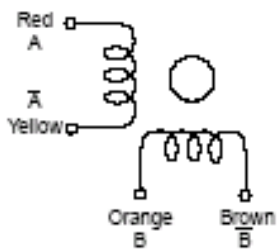
Motors

GBM is an ISO-9001 Certified Company

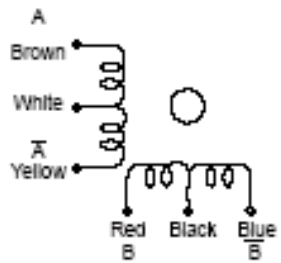
GBM Bipolar and Unipolar Stepper Motors

- Bearing type: ball
- Dielectric strength: 500V, 50Hz/minute
- 18" lead wires
- Step angle: 1.8°
- Ambient temperature: -10°C to +55°C
- Insulation resistance: 100MΩ @ 500VDC
- Use P/N 161998, pg 162, for shaft coupler

Bipolar (Fig. 1)



Unipolar (Fig. 2)



† NEMA 17

† NEMA 23

Part Number	Product Number	Fig.	NEMA† Form	No. of Phases	Drive System	Voltage (VDC)	Phase Resistance (Ohms)	Current (mA)	Phase Inductance (mH)	Detent Torque (g-cm)	Holding Torque (g-cm)	Mounting Hole Space Diagonal (in.)	Mounting Holes (in.)	Shaft Diameter (in.)	Shaft Length (in.)	Motor Diameter (in.)	Motor Height (in.)	Weight (lbs.)	Pricing 1	Pricing 10	Pricing 50
155432	42BYG228	2	17	4	Unipolar	12	30	400	23	220	2,000	1.73	0.1	0.197	0.9	1.7	1.5	0.5	$17.95	$16.29	$14.59
155459	42BYG023*	1	17	2	Bipolar	12	30	400	36	220	2,100	1.73	0.1	0.197	0.6	1.7	1.3	0.5	17.95	16.29	14.59
172646	42BYG205	2	17	4	Unipolar	9.6	75	480	15	220	2,300	1.73	0.1	0.197	0.9	1.7	1.4	0.5	14.95	13.49	11.95
162026	57BYG084	2	23	4	Unipolar	12	20	600	22	725	6,000	2.65	0.2	0.250	1.0	2.2	2.0	1.3	26.95	24.29	21.85
206025	23PMC10804	2	23	4	Unipolar	5.4	8	1500	56	1300	20,000	2.65	0.2	0.184	0.9	2.2	3.0	1.9	29.95	26.95	24.25

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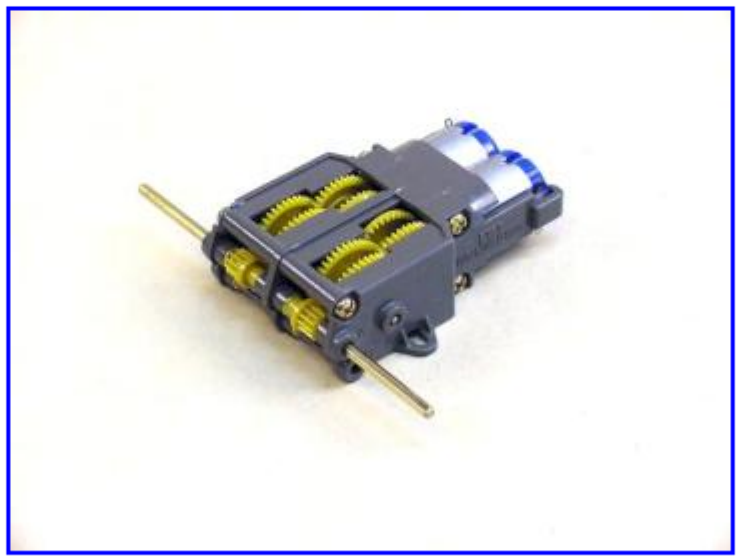

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Reduction = 203:1 or 58:1
Stall Torque = 124 or 36 oz-in (8.9 or 2.6 kg-cm)
Wheels = Sport (STS-01), Off Road (ORT-01), Truck (ORT-02)

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Weight [0.25]

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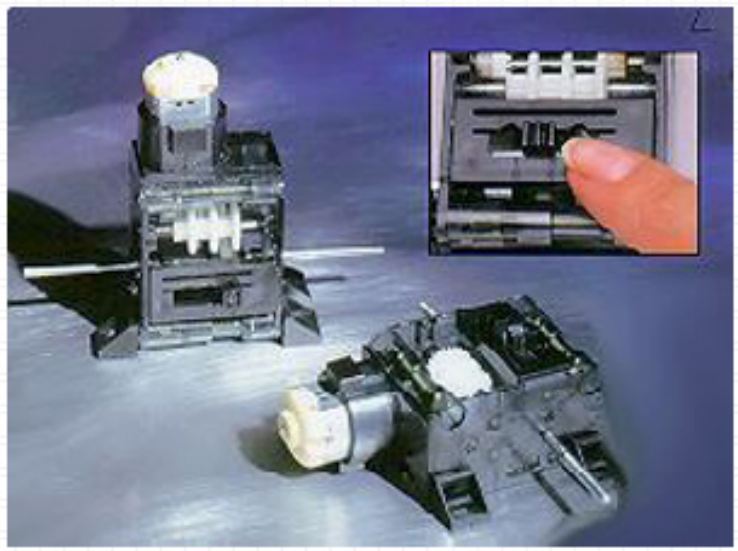

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Dual Motor Gearbox Kit

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Width = 1.0"
Motor = Dual Motor Gearbox
(DMG-01)

Price [$7.95]
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Weight [0.19]

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