

Interfacing Motors to the Handy Board

Pre-Lab Questions

1. What is the stall torque of the Mabuchi FF-030PN motor assuming 4.7 V is applied to its terminals?
2. What is the no load speed of the Mabuchi FF-030PN motor assuming 4.7 V is applied to its terminals?
3. If there are only 4 wires coming from a stepper motor, what kind of stepper is it?
4. What pulse duration is needed to position the output shaft of an R/C servo in the center of its rotational range?

Learning Objectives for the Student

- **Interface** a DC motor to the Handy Board
- **Interface** an R/C servo to the Handy Board
- **Interface** a stepper motor to the Handy Board
- **Write** programs in IC that will control the speed and direction of each of the actuators listed above

Components

<u>Qty.</u>	<u>Item</u>
1	Handy Board with expansion board and serial interface/charger
1	Serial cable with DB-9 to DB-25 adapter
1	RJ-11 cable
1	10 Ω resistor
1	74LS04 hex inverter IC
1	ULN2803 octal peripheral driver
2	3-pin double-ended male header
1 ft	28 AWG stranded cable (a pair of wires peeled from ribbon cable)
3.5 in.	1/16 in. dia shrink tubing
1	lever microswitch and connector assembly (from a previous lab)
1	Futaba FP-S148 servo
1	Mabuchi FF-030PN-09210, 4.7V, 9800 RPM dc motor (Jameco 171598)
1	Unipolar stepping motor (Jameco 105890)

Introduction

In this lab you will explore how to interface and control three kinds of actuators: a DC motor, a radio control (R/C) servo, and a stepper motor using the Handy Board.

Brush-type dc motors have two terminals and are designed so that the shaft will rotate *continuously* when an appropriate voltage is placed across the terminals. We will use the

Mabuchi FF-030PN dc motor, which has a nominal operating voltage is 4.7 V. The data sheet for this motor is attached.

A stepping motor, on the other hand, is designed so that its shaft rotates in a discrete *increment* in response to a sequential energization of its windings. Stepper motors are classified as either bipolar or unipolar depending on the configuration of their windings. In a bipolar stepper, in order for current to flow in opposite directions in each *phase* (i.e., independent stator winding), the polarity of the voltage applied to the winding must reverse (hence the name, *bipolar*). In a unipolar stepper, each phase has a center tap, so if current is supplied at the center tap, it can be made to flow in opposite directions through the winding by controlling which end of the winding is allowed to conduct.

An R/C servo consists of a dc motor, gear train, potentiometer, and some control circuitry all mounted compactly in a case. R/C servos are commonly used in radio-controlled cars, airplanes, and boats to provide limited rotational motion to steer, move control surfaces, etc. R/C servos are attractive for educational use in mechatronics, because they are relatively inexpensive (about \$12-\$20), they can put out about 42 oz/in of torque, they can easily be modified to produce continuous shaft rotation at relatively slow speeds, and they can easily be controlled by a microcontroller. There are three wires, white, red, and black on the servo leading from a 3-pin female connector to the case as shown in Figure 1. These carry the control signal, power, and ground return respectively.

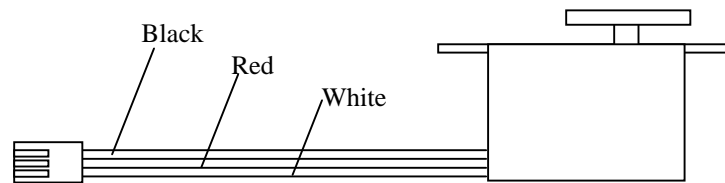


Figure 1 R/C Servo. The R/C servo uses three wires: white carries the control signal, red carries power (usually 4.8 V to 6 V), black is ground.

Figure 2 shows how an R/C servo is made to rotate. The control circuitry inside the servo must receive a stream of pulses whose widths may vary between about 1 ms and 2 ms, and these pulses must occur at intervals of about 10 to 20 ms. A potentiometer (pot) coupled to the rotation of the output shaft produces a voltage corresponding to the angle of the shaft. The control circuitry compares the “average” voltage of the control signal with the voltage from the pot, and the shaft rotates until the two voltages are the same. The control circuitry is designed so that the speed of rotation is proportional to the difference between the control signal voltage and the pot voltage.

Procedure

DC Motor (2 people build the hardware, 2 write the software)

1. Make a connector for the DC motor using one of the single row, 3-pin male headers and the pair of 28 AWG wires. The center pin can be clipped off, because it plugs into a socket that is unconnected on the Handy Board motor port. Be sure to slide some short lengths of shrink fit tubing over the ends of the wire before you solder them to the connector.

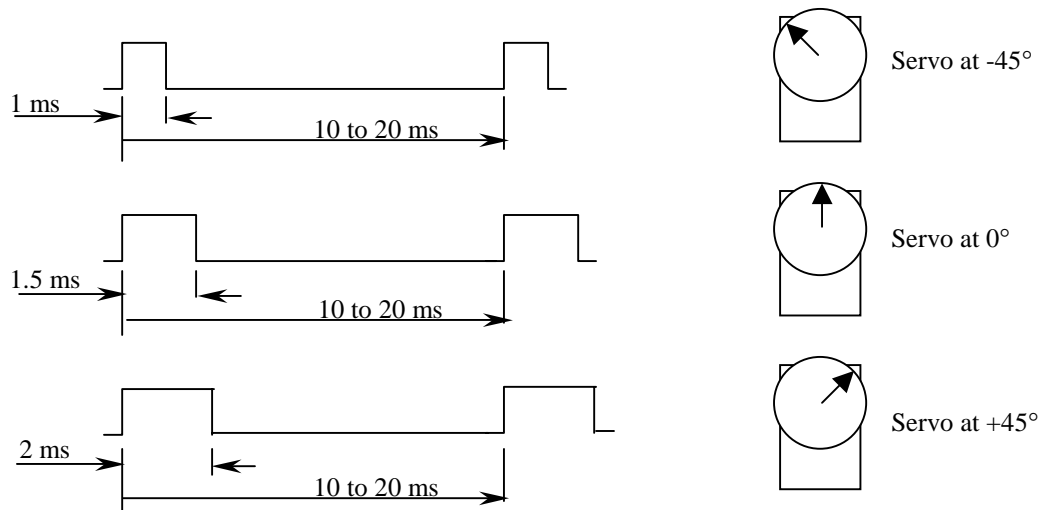
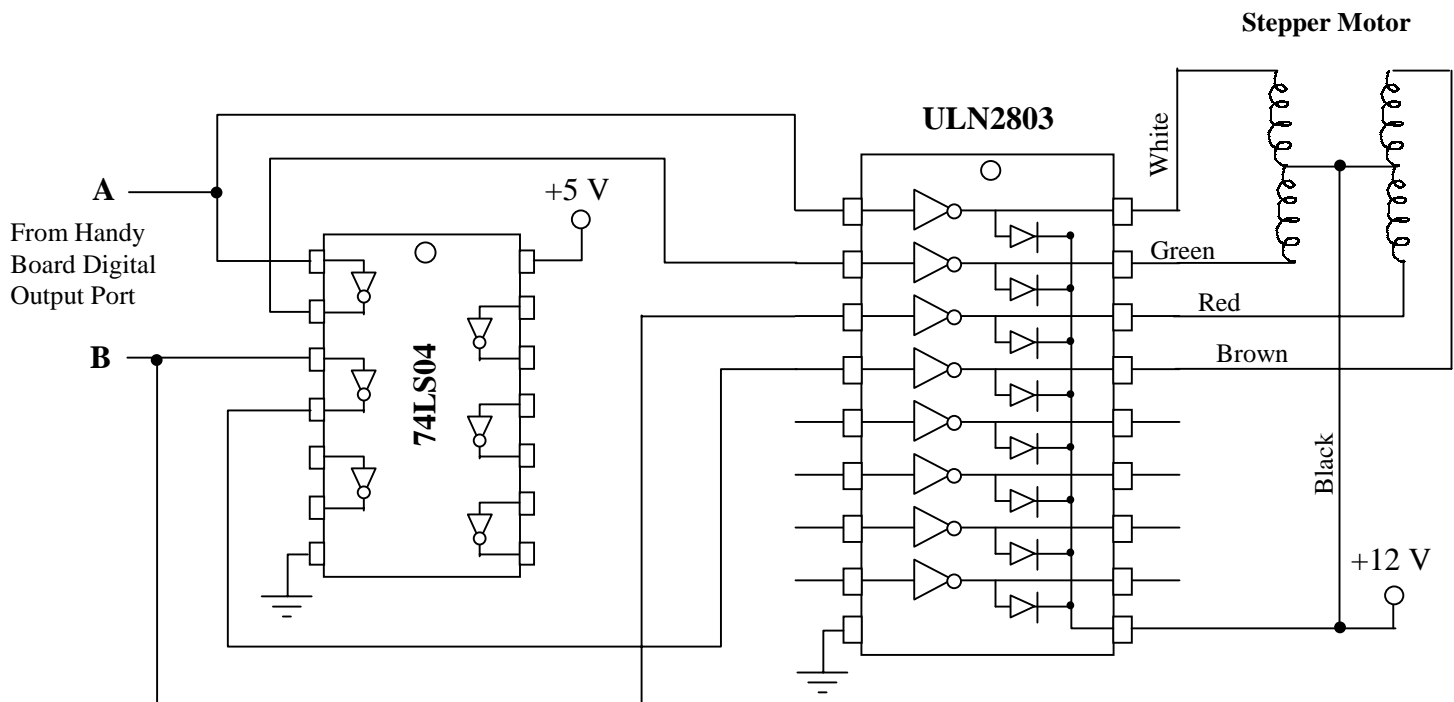


Figure 2 R/C Servo Operation. The R/C servo needs to see a pulse-width modulated control signal in order to position the output shaft. Pulse-widths vary between approximately 1ms - 2 ms, and have a period of 10 ms - 20 ms

2. Unsolder the two wires that come pre-attached to the motor. Solder the other end of the pair of wires you used in step 1 to the motor. Again, be sure to put on the shrink tubing before you solder the wires to the motor.
3. Splice a 10 Ω resistor into one of the wires about 1.5 inches from the connector. (Trim the leads of the resistor to about 1/4 inch long before you solder them to the wires.) Be sure to put on shrink tubing before you solder the wires to the resistor.
4. Shrink the tubing using the heat gun.
5. Plug the connector into the one of the MOT pins of the motor port on the Handy Board.
6. Write a program in IC that will enable you to turn the motor on and off by sensing the state of a lever microswitch (assembled from a previous lab).
7. Write a program in IC that will enable you to control the speed of the motor depending on the knob setting (the potentiometer on the Handy Board).

Stepper Motor (2 people build the hardware, 2 write the software)

1. Make a connector for the white, green, red, and brown stepper motor wires using one of the single row, 4-pin male headers and the pair of 28 AWG wires. Solder the wires to the header pins in the order: white, green, red, brown. Be sure to slide some short lengths of shrink fit tubing over the ends of the wire *before* you solder them to the connector.
2. Solder a single male header pin to the black lead from the stepper motor. Be sure to slide a short length of shrink fit tubing over the end of the wire *before* you solder it to the pin. The black wire is the common center tap, and it is to this lead that power will be applied. Shrink the tubing after you are finished soldering.
3. Build the driver from the schematic shown in Figure 3. **IMPORTANT NOTE:** in order to function properly, make sure that the power supply common and digital ground from the



Step Sequence

A	B
1	1
0	1
0	0
1	0
Repeat	

Figure 3 Stepper Motor Driver Circuit. A unipolar stepper motor can be driven by two digital outputs from the Handy Board, a 74LS04 Hex Inverter, and a darlington driver like the ULN2803. Note that power is supplied to the motor from an external 12 V power supply. In order to function properly, make sure that the power supply common and digital ground from the Handy Board are tied together.

Handy Board are tied together. The outside row of female sockets of the digital input port on the HB is digital ground.

4. Connect the driver as shown in Figure 3 to the Handy Board.
5. Write a program in IC that will step the motor continuously in one direction. Note that you will need a delay between steps to give time for the rotor to move
6. Write an IC program that will enable you to control the speed of the motor by the position of the user knob.

Servo Motor (2 people build the hardware, 2 write the software)

1. Look at the connector at the end of the servo before you do anything with it. IT IS EXTREMELY IMPORTANT TO MAKE THE CONNECTION TO THE HANDY

BOARD CORRECTLY, OR ELSE THE SERVO ELECTRONICS WILL BE INSTANTLY FRIED (and you'll have to shell out \$15 to buy the lab another servo). Orient the connector to match the colors of the wires as shown in Figure 4.

- Write a program in IC that will allow you to control the orientation of the servo output shaft from the User Knob. In other words, the servo should rotate in lock-step with the User Knob. See the Expansion Board Software Libraries web page for more details. (<http://handyboard.com/hbexp30/software.html>):

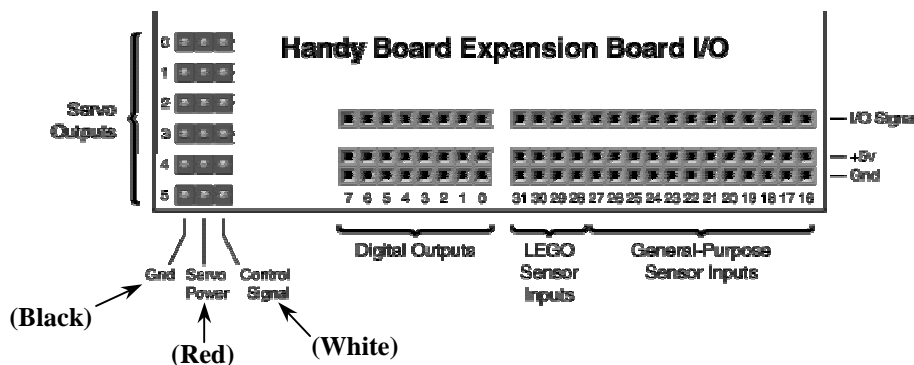


Figure 4 Servo pin-outs. Make the connection correctly to avoid damaging the servo. See <http://handyboard.com/hbexp30/software.html> for more information.

End Notes

Take some time to consult with your classmates about the motors and code they worked on, and shown them what you did with your motor.

Each set of two pairs of students can turn in a common report on the interfacing and control of the motor they worked on.

It is relatively easy to modify a servo so that it can rotate continuously. An excellent step-by-step guide for doing so can be found at:

<http://www.seattlerobotics.org/guide/servohack.html>

If you use the Futaba FP-S148, it is especially easy. You don't even need to replace the potentiometer as noted in the link above.

Once you've hacked the servo, by varying the pulse-width as you did in this lab, you then have a low-cost, relatively powerful variable speed dc motor drive. If you manually position the pot shaft to its center position, then by varying the pulse width over the range used in this experiment, you will be able to control the motor speed and direction of rotation.

Using a servo for can be a low-cost, efficient approach for giving mobility to your robot. Tower Hobbies (<http://www.towerhobbies.com/>) has the best prices around for Futaba servos (3 for \$39.47).

Jameco Part number 105890

JAMECO

ELECTRONIC COMPONENTS
COMPUTER PRODUCTS

Part No. 105890

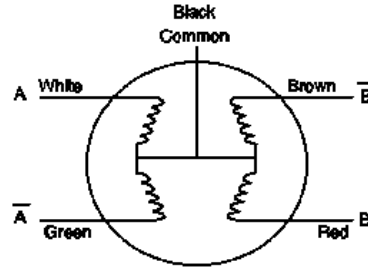
Product No. SM4200

4 Phase Unipolar Stepper Motor

1355 Shoreway Rd., Belmont, CA 94002 * Tel: 415-592-8097 * Fax: 415-592-2503 * BBS: 415-637-9025

Specifications:

Unipolar (4 Phase)
12 VDC, 150mA
Coil: 75 Ohm, 39mH
3.6 degrees/step
Shaft: 0.19"D x 0.43"L
Mounting Hole Spacing: 1.73"
Mounting Hole Diameter: 0.11"
Motor: 1.66"D x 1.35"H
Detent Torque: 80 g-cm
Holding Torque: 600 g-cm
Weight: 0.5 Lbs.

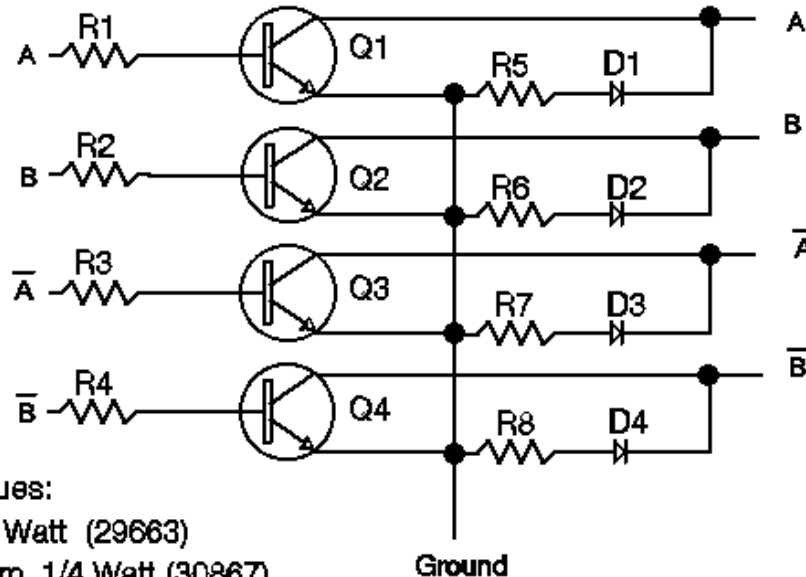


Step	A	B	\bar{A}	\bar{B}	Common
1	-	-			+
2		-	-		+
3			-	-	+
4	-			-	+
5	-	-			+

Applications:

Automation
Robotic Control
Precision Mechanical Control

Driver Schematic



Suggested Values:

R1-R4=1K, 1/4 Watt (29663)
R5-R8=330 Ohm, 1/4 Watt (30867)
Q1-Q4=MJE3055T (25857)
D1-D4=1N4003 (76970)

54LS04/DM54LS04/DM74LS04 Hex Inverting Gates

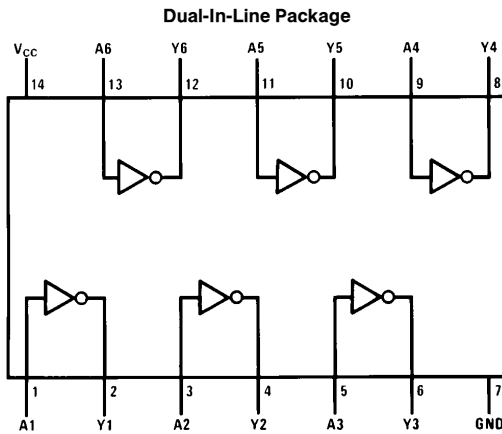
General Description

This device contains six independent gates each of which performs the logic INVERT function.

Features

- Alternate Military/Aerospace device (54LS04) is available. Contact a National Semiconductor Sales Office/Distributor for specifications.

Connection Diagram



TL/F/6345-1

Order Number 54LS04DMQB, 54LS04FMQB, 54LS04LMQB, DM54LS04J, DM54LS04W, DM74LS04M or DM74LS04N
See NS Package Number E20A, J14A, M14A, N14A or W14B

Function Table

$$Y = \bar{A}$$

Input	Output
A	Y
L	H
H	L

H = High Logic Level
L = Low Logic Level

Absolute Maximum Ratings (Note)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

Supply Voltage	7V
Input Voltage	7V
Operating Free Air Temperature Range	
DM54LS and 54LS	–55°C to +125°C
DM74LS	0°C to +70°C
Storage Temperature Range	–65°C to +150°C

Note: The “Absolute Maximum Ratings” are those values beyond which the safety of the device cannot be guaranteed. The device should not be operated at these limits. The parametric values defined in the “Electrical Characteristics” table are not guaranteed at the absolute maximum ratings. The “Recommended Operating Conditions” table will define the conditions for actual device operation.

Recommended Operating Conditions

Symbol	Parameter	DM54LS04			DM74LS04			Units
		Min	Nom	Max	Min	Nom	Max	
V _{CC}	Supply Voltage	4.5	5	5.5	4.75	5	5.25	V
V _{IH}	High Level Input Voltage	2			2			V
V _{IL}	Low Level Input Voltage			0.7			0.8	V
I _{OH}	High Level Output Current			–0.4			–0.4	mA
I _{OL}	Low Level Output Current			4			8	mA
T _A	Free Air Operating Temperature	–55		125	0		70	°C

Electrical Characteristics over recommended operating free air temperature range (unless otherwise noted)

Symbol	Parameter	Conditions	Min	Typ (Note 1)	Max	Units
V _I	Input Clamp Voltage	V _{CC} = Min, I _I = –18 mA			–1.5	V
V _{OH}	High Level Output Voltage	V _{CC} = Min, I _{OH} = Max, V _{IL} = Max	DM54 2.5	3.4		V
V _{OL}	Low Level Output Voltage	V _{CC} = Min, I _{OL} = Max, V _{IH} = Min	DM54 0.25	0.25	0.4	V
		I _{OL} = 4 mA, V _{CC} = Min	DM74 0.35	0.35	0.5	
I _I	Input Current @ Max Input Voltage	V _{CC} = Max, V _I = 7V			0.1	mA
I _{IH}	High Level Input Current	V _{CC} = Max, V _I = 2.7V			20	μA
I _{IL}	Low Level Input Current	V _{CC} = Max, V _I = 0.4V			–0.36	mA
I _{OS}	Short Circuit Output Current	V _{CC} = Max (Note 2)	DM54 –20		–100	mA
			DM74 –20		–100	
I _{CCH}	Supply Current with Outputs High	V _{CC} = Max		1.2	2.4	mA
I _{CCL}	Supply Current with Outputs Low	V _{CC} = Max		3.6	6.6	mA

Switching Characteristics at V_{CC} = 5V and T_A = 25°C (See Section 1 for Test Waveforms and Output Load)

Symbol	Parameter	R _L = 2 kΩ				Units
		C _L = 15 pF		C _L = 50 pF		
		Min	Max	Min	Max	
t _{PLH}	Propagation Delay Time Low to High Level Output	3	10	4	15	ns
t _{PHL}	Propagation Delay Time High to Low Level Output	3	10	4	15	ns

Note 1: All typicals are at V_{CC} = 5V, T_A = 25°C.

Note 2: Not more than one output should be shorted at a time, and the duration should not exceed one second.



MOTOROLA

Order this document by ULN2803/D

Octal High Voltage, High Current Darlington Transistor Arrays

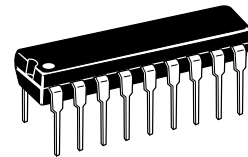
The eight NPN Darlington connected transistors in this family of arrays are ideally suited for interfacing between low logic level digital circuitry (such as TTL, CMOS or PMOS/NMOS) and the higher current/voltage requirements of lamps, relays, printer hammers or other similar loads for a broad range of computer, industrial, and consumer applications. All devices feature open-collector outputs and free wheeling clamp diodes for transient suppression.

The ULN2803 is designed to be compatible with standard TTL families while the ULN2804 is optimized for 6 to 15 volt high level CMOS or PMOS.

ULN2803 ULN2804

OCTAL PERIPHERAL DRIVER ARRAYS

SEMICONDUCTOR TECHNICAL DATA



A SUFFIX
PLASTIC PACKAGE
CASE 707

MAXIMUM RATINGS ($T_A = 25^\circ\text{C}$ and rating apply to any one device in the package, unless otherwise noted.)

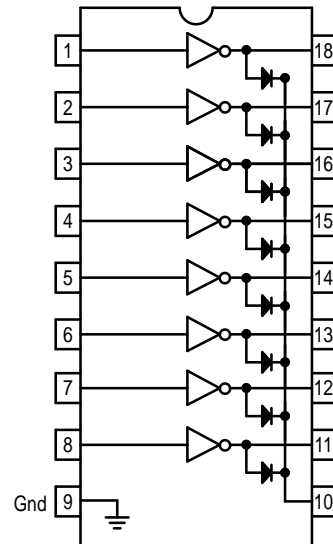
Rating	Symbol	Value	Unit
Output Voltage	V_O	50	V
Input Voltage (Except ULN2801)	V_I	30	V
Collector Current – Continuous	I_C	500	mA
Base Current – Continuous	I_B	25	mA
Operating Ambient Temperature Range	T_A	0 to +70	$^\circ\text{C}$
Storage Temperature Range	T_{stg}	-55 to +150	$^\circ\text{C}$
Junction Temperature	T_J	125	$^\circ\text{C}$

$R_{\theta JA} = 55^\circ\text{C/W}$
Do not exceed maximum current limit per driver.

ORDERING INFORMATION

Device	Characteristics		
	Input Compatibility	$V_{CE(\text{Max})}/I_{C(\text{Max})}$	Operating Temperature Range
ULN2803A ULN2804A	TTL, 5.0 V CMOS 6 to 15 V CMOS, PMOS	50 V/500 mA	$T_A = 0 \text{ to } +70^\circ\text{C}$

PIN CONNECTIONS



ULN2803 ULN2804

ELECTRICAL CHARACTERISTICS ($T_A = 25^\circ\text{C}$, unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
Output Leakage Current (Figure 1) ($V_O = 50\text{ V}$, $T_A = +70^\circ\text{C}$) ($V_O = 50\text{ V}$, $T_A = +25^\circ\text{C}$) ($V_O = 50\text{ V}$, $T_A = +70^\circ\text{C}$, $V_I = 6.0\text{ V}$) ($V_O = 50\text{ V}$, $T_A = +70^\circ\text{C}$, $V_I = 1.0\text{ V}$)	All Types All Types ULN2802 ULN2804	I_{CEX}	– – – –	– – – –	100 50 500 500	μA
Collector–Emitter Saturation Voltage (Figure 2) ($I_C = 350\text{ mA}$, $I_B = 500\text{ }\mu\text{A}$) ($I_C = 200\text{ mA}$, $I_B = 350\text{ }\mu\text{A}$) ($I_C = 100\text{ mA}$, $I_B = 250\text{ }\mu\text{A}$)	All Types All Types All Types	$V_{CE(sat)}$	– – –	1.1 0.95 0.85	1.6 1.3 1.1	V
Input Current – On Condition (Figure 4) ($V_I = 17\text{ V}$) ($V_I = 3.85\text{ V}$) ($V_I = 5.0\text{ V}$) ($V_I = 12\text{ V}$)	ULN2802 ULN2803 ULN2804 ULN2804	$I_{I(on)}$	– – – –	0.82 0.93 0.35 1.0	1.25 1.35 0.5 1.45	mA
Input Voltage – On Condition (Figure 5) ($V_{CE} = 2.0\text{ V}$, $I_C = 300\text{ mA}$) ($V_{CE} = 2.0\text{ V}$, $I_C = 200\text{ mA}$) ($V_{CE} = 2.0\text{ V}$, $I_C = 250\text{ mA}$) ($V_{CE} = 2.0\text{ V}$, $I_C = 300\text{ mA}$) ($V_{CE} = 2.0\text{ V}$, $I_C = 125\text{ mA}$) ($V_{CE} = 2.0\text{ V}$, $I_C = 200\text{ mA}$) ($V_{CE} = 2.0\text{ V}$, $I_C = 275\text{ mA}$) ($V_{CE} = 2.0\text{ V}$, $I_C = 350\text{ mA}$)	ULN2802 ULN2803 ULN2803 ULN2803 ULN2804 ULN2804 ULN2804 ULN2804	$V_{I(on)}$	– – – – – – – –	– – – – – – – –	13 2.4 2.7 3.0 5.0 6.0 7.0 8.0	V
Input Current – Off Condition (Figure 3) ($I_C = 500\text{ }\mu\text{A}$, $T_A = +70^\circ\text{C}$)	All Types	$I_{I(off)}$	50	100	–	μA
DC Current Gain (Figure 2) ($V_{CE} = 2.0\text{ V}$, $I_C = 350\text{ mA}$)	ULN2801	h_{FE}	1000	–	–	–
Input Capacitance		C_I	–	15	25	pF
Turn–On Delay Time (50% E_I to 50% E_O)		t_{on}	–	0.25	1.0	μs
Turn–Off Delay Time (50% E_I to 50% E_O)		t_{off}	–	0.25	1.0	μs
Clamp Diode Leakage Current (Figure 6) ($V_R = 50\text{ V}$)	$T_A = +25^\circ\text{C}$ $T_A = +70^\circ\text{C}$	I_R	–	–	50 100	μA
Clamp Diode Forward Voltage (Figure 7) ($I_F = 350\text{ mA}$)		V_F	–	1.5	2.0	V