Repeater and Remote Base Applications of the FC-1 Frequency Control Board

Introduction

All of ACC's repeater and remote base products support control of synthesized remote base transceivers. One form of frequency control supported is compatible with transceivers using thumbwheel frequency selection. The controllers supply BCD (binary coded decimal) formatted data in a serial bit stream, which may be captured by external shift registers to drive the transceiver's frequency synthesizer, simulating the thumbwheel switches.

Applications

The FC-1 board may be used with the RC-850 and RC-85 Repeater Controllers, the ITC-32 Intelligent Touch-Tone Control Board and ShackMaster. It provides the frequency control interface for the ICOM IC-2A, IC-3A, or IC-4A transceiver. With minor modifications, it may control certain other BCD format transceivers. In addition, it can recover expanded remote control output functions for several of the controllers. The applications include:

RC-850 Repeater Controller ...
Control IC-2/3/4A on Link 1 *or* Recover 32 Expanded UF Outputs

RC-85 Repeater Controller ...
Control IC-2/3/4A on Link *and* Recover 8 Expanded UF Outputs

ITC-32 Intelligent Touch-Tone Control Board ...
Control IC-2/3/4A on Link

ShackMaster ...
Control IC-2/3/4A as primary or secondary transceiver
and Control IC-751 HF rig through its keypad connector
and Recover 8 Expanded Control Outputs

The board is useful for controlling an IC-2/3/4A with any ACC controller. It may be adapted for the other applications listed above, but in some cases it may be simpler to duplicate its circuitry or the circuitry in the controller manual in another format better suited to the application.

Warning: Connection of the FC-1 to the ICOM transceiver is not a beginner's project. It requires suitable construction equipment including a temperature controlled soldering station, and suitable test equipment such as a good meter or oscilloscope. It also requires relatively advanced construction and troubleshooting skills and an understanding of digital circuitry. ACC specifically disclaims responsibility for damage which may result to your transceiver.

While the FC-1 may be modified to control a variety of BCD controllable transceivers, ACC has direct experience with only certain transceivers, as described in this note. We welcome your input on successful interfaces to other transceivers, and we will make this information available to others on an *as-is* basis on request. We regret that we can provide technical assistance only for those transceivers with which we have direct experience.

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FC-1 Frequency Control Board

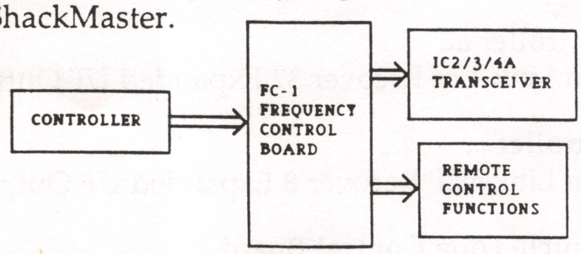
This application note contains the following information:

- System Block Diagram
- Board Layout and Suggested Enclosure
- Control of the IC2/3/4A Transceiver
- Modifications for Control of the ICOM IC-22U 2M Transceiver
- Recovering RC-85 Controller Expanded UF Outputs
- Recovering RC-850 Controller Expanded UF Outputs
- How It Works
- Most Often Asked Questions ... and Answers
- Schematic
- IC Data Sheets

System Block Diagram

The FC-1 board fits into a repeater or remote base system as shown below. It is driven by the controller and supplies frequency information to the BCD controllable transceiver.

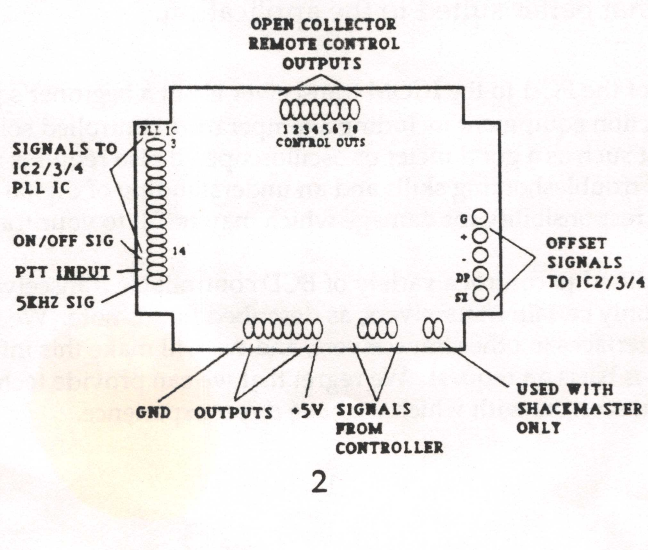
The FC-1 board can also provide expanded general purpose remote control outputs when the controller includes this capability as part of the serial bit stream, such as the RC-85 controller and ShackMaster.



Board Layout and Suggested Enclosure

The layout of the FC-1 board is shown below. Several of the circuits on the board apply only to ShackMaster and are labeled as they apply to the ShackMaster application of interfacing to the ICOM IC-751 HF transceiver keypad connector.

The FC-1 board may be mounted in any way convenient in your installation, but it is designed to fit directly into a Unibox 130 standard enclosure, manufactured by Amerex, P.O. Box 2815, Riverside, CA 92516, (714) 686-1400. Uniboxes are available from many electronic suppliers. The Unibox enclosure is plastic. It may be preferable to use an rf tight metal enclosure, depending on your installation.



Control of the IC-2/3/4A Transceiver

The ICOM IC-2/3/4A transceivers are low cost synthesized handheld rigs which are easily controllable with external BCD frequency and offset logic signals.

Enclosure

For applications in high rf environments, it may be necessary to mount the transceiver in an rf tight enclosure, such as a Bud Econobox, for optimum performance. Signals entering and leaving the enclosure may go through feedthrough capacitors, as with any high performance repeater rf equipment.

The FC-1 board may mount inside the enclosure with the transceiver to minimize the number of I/O lines requiring feedthrough capacitors. Be careful about degrading the rise times of the clock and data signals from the controller – it may be necessary to reduce the pullup resistors (R1, R2 and R3) to 1K to restore fast rise times when capacitance is attached to the lines. At low rf sites or where optimum performance isn't required, no special packaging considerations should be necessary.

Interface to Controller

The FC-1 board receives the serially encoded frequency and offset information from the controller, performs the serial-to-parallel conversion, and provides the logic to interface to the transceiver's offset circuitry. The controller provides serial data and clock (or strobe) as follows:

Controller	Data	Clock	Transfer
RC-850	UF7	UF Strobe	---
RC-85	CX 1	CX 2	CX 3 (optional)
ITC-32	OUT 7	OUT 6	---
ShackMaster	DATA	CLK	XFER

The FC-1 board includes a transfer (XFER) logic input which transfers the outputs of the shift registers to a set of storage registers (inside the 4094 IC's) after the data has been shifted out. The transfer logic input is optionally used with the RC-85 and ShackMaster and prevents "glitches" from appearing at the FC-1 expanded remote control outputs. The XFER input is left open (internally pulled up) with the '850 and ITC-32 controllers.

Power Supply

The synthesizer logic inside the IC-2/3/4A transceivers operates from 5 volts, so this dictates the operating voltage of the logic supplying the control signals. The 5 volt supply for the board may be obtained from inside the radio.

Interface to Transceiver

BCD Lines – The outputs of the first two shift/store registers drive the PLL IC inside the radio directly. These are the BCD frequency control signals developed in response to user commands to the controller. The additional logic develops the offset signals required on transmit. They connect inside the radio as described below. The BCD signals may connect directly to the PLL IC underneath the transceiver's p.c. board. The thumbwheel switches must be *set to all 0's* so they don't short out the signals supplied from the FC-1.

Offset Signals – The offset switches in the radio may be removed to open the internal paths for the offset signals. Note that the PTT input (described below) *must* be connected to the controller output driving the radio PTT to activate the offset circuitry. Otherwise, the transmitter will be inhibited.

PTT – The active low open collector PTT signal from the controller should drive the radio through a resistor (around 2.2K) to the base of the switching transistor (IC-2A - Q23; IC-3A - Q23; IC-4A - Q26). Driving the switching transistor directly rather than through the DC path from the PTT switch helps eliminate keying problems when applying audio. *Be sure to cut the trace or clip the resistor from the microphone to the base of the keying transistor.* This will prevent spurious keying by applied audio.

The PTT signal from the controller driving the transceiver must also connect to the PTT input of the FC-1 board to activate the offset circuitry.

With the RC-85 controller in the Glitch-Free mode, the controller's PTT output appears at the FC-1 Control Out 1 (UF8). If not in the Glitch-Free mode, the PTT appears at CX3.

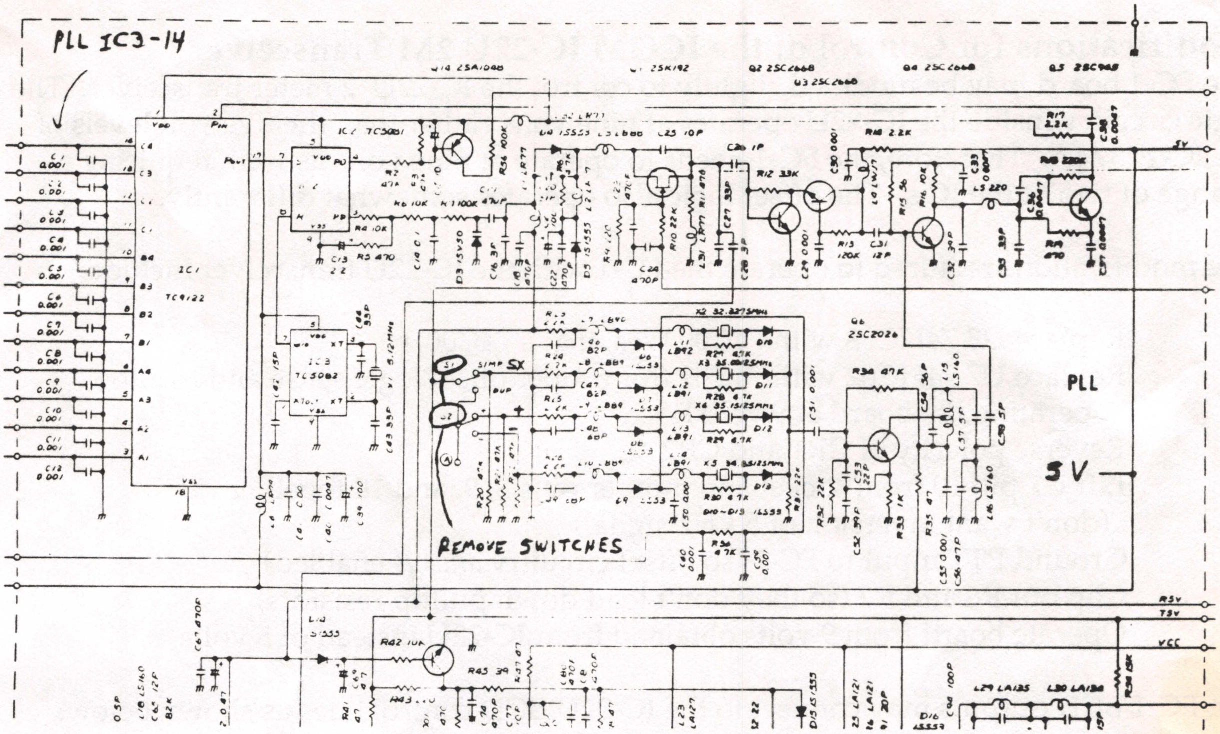
COS – The active high COS signal is available from the audio stage – the audio output amp is powered up only when a signal is received. The switched supply voltage becomes the COS available to the controller at the collector of IC-2A – Q16; IC-3A – Q16; IC-4A – Q17.

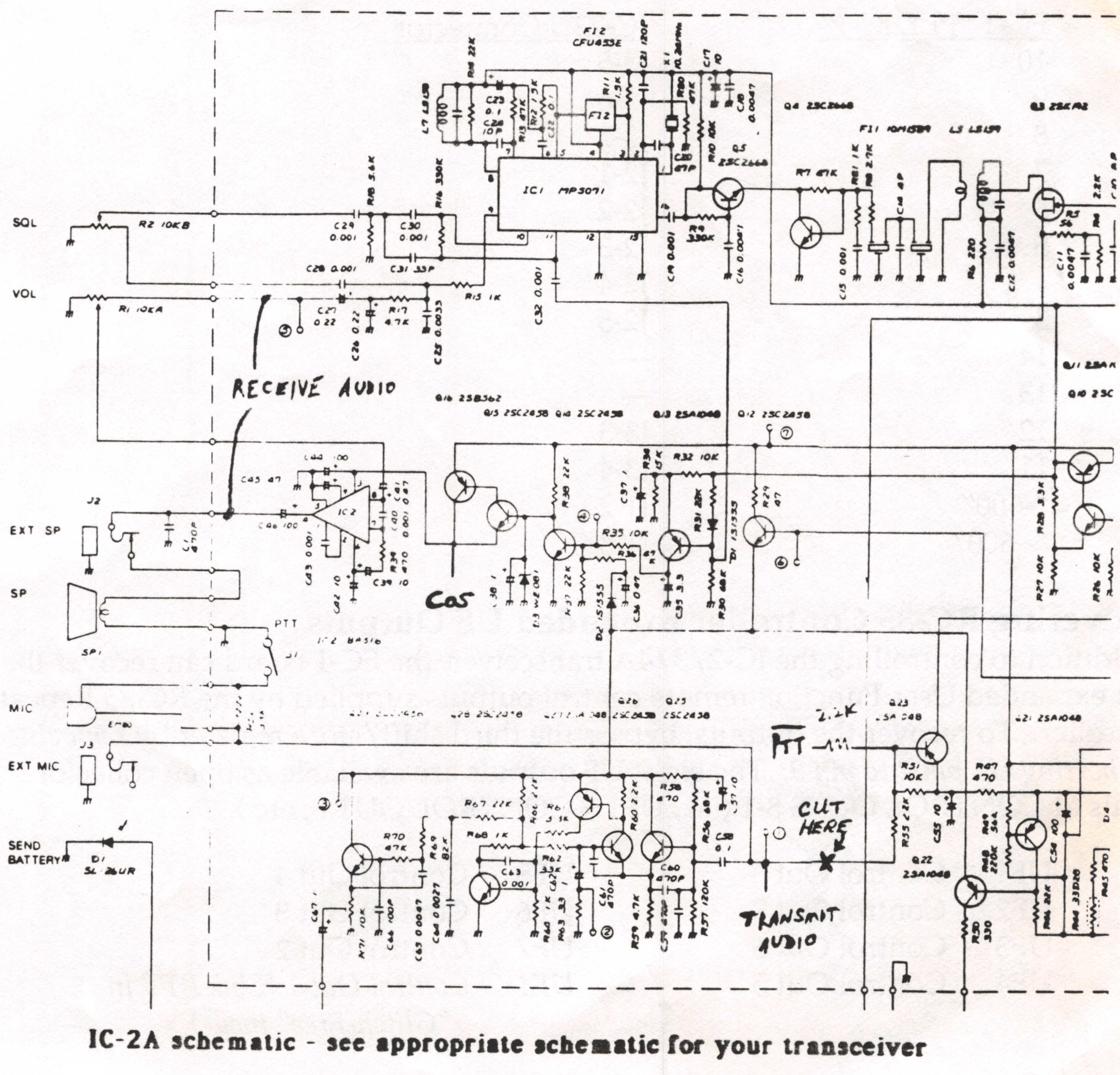
Receive Audio to the controller (or to user supplied circuitry in the case of the ITC-32) is easily obtained from the top of the volume control pot in the receiver. The level may be too low to directly drive the RC-850 or RC-85 controller, but the RC-850 controller input sensitivity can be increased by installing a 4.7K resistor at R87. An acceptable alternative is simply getting speaker audio at the phone jack.

Transmit audio to the IC-2/3/4A should be taken from the RC-850, RC-85, or ShackMaster Transmitter Audio output, or from the repeater receiver in the case of the ITC-32. The audio may be applied through a potentiometer wired as a variable voltage divider for transmit audio level adjustment.

FC-1	IC2A	IC3A	IC4A
PLL3-14	PLL IC pins 3-14		
On/off	not used		
PTT	through 2.2K to base Q23 *and to controller PTT*		(Q26)
0/5 KHz	S2	nc	S2
Simplex	R24	R30	R25
Duplex	-	R31	-
+	R25	nc	R62
-	R26	nc	R24
+5V	internal "5V"		
Ground	ground		
Controller			
COS	Coll Q16	Coll Q16	Coll Q17
Rcvr audio	top of volume pot or speaker		
Tx audio	external mic input		

IC-2A/AT/E SCHEMATIC DIAGRAM





IC-2A schematic - see appropriate schematic for your transceiver

Modifications for Control of the ICOM IC-22U 2M Transceiver

The FC-1 board may be modified slightly to control the IC-22U 2 meter transceiver. The logic circuitry inside the IC-22U operates at nine volts rather than the five volt levels of the IC-2/3/4A. Therefore, the FC-1 needs to operate at nine volts as well, requiring a change of two of the IC's. The offset logic also operates somewhat differently.

The modifications required to operate the FC-1 with the IC-22U transceiver include:

Replace U8 74HC08 with 74C00 (yes, that's 74C00)
Replace U7 74HC02 with 74C02 (for proper offset logic sense and to allow operating the board at 9 volts)
Reverse polarity of CR1 and CR2
Lift U7 pin 10 from socket and jumper pins 8, 9, and 10 together (don't want inversion of 5 kHz signal)
Ground PTT input to FC-1 (so offset circuitry *always* enabled)
Clip out R6 and R7 (so they don't load down pullup resistors)
Operate board from 9 volts obtained from IC-22U instead of 5 volts

The FC-1 BCD outputs may connect to the IC-22U BCD control lines as shown below:

FC-1 "PLL IC-1"	IC-22U Connector
10	J3-5
9	J3-6
8	J3-7
7	J2-1
6	J2-2
5	J2-3
4	J2-4
3	J2-5
14	---
13	---
12	J3-3
11	J3-4
"-600"	J1-2
"+600"	J1-3

Recovering RC-85 Controller Expanded UF Outputs

In addition to controlling the IC-2/3/4A transceiver, the FC-1 board can recover the eight expanded User Function remote control outputs supplied by the RC-85 Repeater Controller. To recover the outputs, bypass the third shift/store register by *removing U3 and shorting U3 pin 2 to pin 9*. The eight UF outputs are available as open collector signals at CONTROL OUTS 8-1 (i.e., UF1 = CONTROL OUT 8, etc.).

UF1	Control Out 8	UF5	Control Out 4
UF2	Control Out 7	UF6	Control Out 3
UF3	Control Out 6	UF7	Control Out 2
UF4	Control Out 5	*UF8*	*Control Out 1 (Link PTT in "Glitch-Free" mode)*

Recovering RC-850 Controller Expanded UF Outputs

The FC-1 Frequency Control Board can recover 32 of the 64 expanded User Function remote control logic outputs from the RC-850 controller, although because of the board layout, it may be simpler to build the shift register circuitry as shown in the '850 Hardware Reference Manual.

The "expanded mode" programming command should be executed on the '850 to inform it of the presence of the FC-1 board. The signals from the '850 to the FC-1 are as follows:

RC-850 Controller	FC-1 Board
UF1	DATA
UF2	CLK
UF3	XFER
GNDD	GND

The board may be operated at any supply voltage ranging from five to fifteen volts. The operating voltage determines the voltage swing of the recovered outputs. If operated at other than five volts, ICs U7 and U8 *must* be removed, since they are five volt devices (the sockets may be left empty). The logic outputs are available at the following terminals:

UF Output	Location	Characteristic
1-8	PLL IC 10-3	CMOS
9	ON/OFF	CMOS
10	U7 pin 8	CMOS
11	U7 pin 6	CMOS
12	U7 pin 5	CMOS
13-16	PLL IC 14-11	CMOS
17-22	KEY 0 -4, SPK	CMOS
23	U3 pin 12 (R5)	CMOS
24	U3 pin 11 (R4)	CMOS
25-32	CONTROL OUTS 1-8	Open Collector

How It Works

The FC-1 board is simply a set of digital shift registers which perform a serial-to-parallel conversion of the data stream supplied by the controllers. In addition, offset logic is included to directly interface to the IC-2/3/4A transceivers.

<u>Shift Registers</u>

The shift/store registers are 4094B 8-stage shift/store registers with three-state outputs. They combine an 8-stage shift register with a data latch for each stage and a three-state output from each latch. Data applied to the shift register is shifted in on the positive clock transition. Shift registers are cascaded by applying the output from the last stage of one register to the data input of the next. The clock signal drives each shift register in parallel. In the FC-1 board, the logic outputs are kept continuously enabled by tying the Output Enable pin (15) high.

The signals from the controller include Data, Clock, and optionally, Transfer. When the controller updates the FC-1 board, the information is sent in a rapid burst. The first data entered ends up at the far end (right hand side) of the shift register chain. For each bit, first the data signal is taken high or low, then the clock signal is toggled back and forth to clock the data bit into the shift registers. This process is repeated for each bit in the data stream.

The RC-850 controller clocks out 48 bits from its RB Data and RB Strobe outputs – the last 16 bits are Link/Remote Base 1 frequency information and appear at U1 and U2 for controlling the IC-2/3/4A.

The expanded remote control mode causes 64 bits (UF1-64) to be shifted from UF1, UF2, while UF3 serves as a transfer signal (see below). UF1-32 can be captured at U1-4.

The RC-85 controller clocks out 24 bits – 16 remote base frequency bits appear at U1 and U2 for controlling the IC-2/3/4A, and 8 expanded UF output bits may appear at U4 buffered by U5 (U3 should be bypassed – see "Recovering RC-85 Controller Expanded UF Outputs", below).

The ITC-32 control board clocks out 16 bits when in the serial mode, and again these bits appear at U1 and U2 for controlling the IC-2/3/4A.

ShackMaster clocks out 32 bits, including information for the IC-2/3/4A at U1 and U2, IC-751 control signals at U3, and 8 general purpose remote control outputs appearing at U4 buffered by U5.

After the last bit is clocked out by the controller, a high going transfer pulse may transfer the stabilized data in the shift register to the output latches. In this way, data at the output latches can be kept stable during the shifting process.

If a transfer signal is not supplied by the controller, the FC-1 board holds the transfer inputs of the shift/store registers high so that the shift register outputs always appear at the latch outputs. The result is that while the new data is being shifted in, for a period of about 1 ms, the data at each of the outputs will spuriously change. This isn't a problem for the transceiver, since the disturbance is too short to cause the phase-locked loop to lose lock. It also isn't a problem for any outputs driving relays, since the relay switching time is too long to notice. However, any one-shots or 555s driven by expanded remote control outputs (such as for starting a tape player as an "external device") may be triggered by the "glitches". In this type of application, be sure to use the transfer signal from the controller.

<u>Offset Circuitry</u>
The IC-2A transceiver uses an electronically switched crystal offset oscillator in conjunction with its frequency synthesizer. One crystal is used on receive, electronically switched on by R5V (5 volt supply for the receiver). In transmit, one of three crystals is selected, based on simplex, duplex-plus, or duplex-minus operation. The logic on the FC-1 board uses the simplex/duplex and +/- bits from the controller to decide which crystal to activate. The series diodes isolate the gates from the oscillator when not selected, and the 47K pulldown resistors provide a bleed path to ground.

The offset signals are needed *only* during transmit. Therefore, the FC-1 board logic gates in the PTT signal (PTT input to board) to activate the appropriate offset signal only during transmit. The PTT signal *must* be supplied to the FC-1 offset logic to activate the proper crystal, as well as to the transceiver to key it.

The IC-3A and IC-4A are similar.

<u>Input Characteristics</u>
The Data, Clock, and Transfer inputs are intended to be driven from open collector drivers from the controller. Each controller output presents either an open circuit, in which case the pullup resistor on the FC-1 determines the logic high state, or the output provides a switch closure to ground, forcing a logic low state of zero volts.

If it's necessary to bypass these inputs with a capacitor to keep out rf, don't exceed about 100 pF. Decrease the pullup resistors (R1, R2, and R3) to 1K by paralleling a 1K resistor across the existing 10Ks.

<u>Output Characteristics</u>
BCD Digits (U1, half of U2). These output bits are supplied from the 4094B CMOS shift/store registers. The logic outputs swing between zero volts and the supply voltage. They are capable of sourcing and sinking approximately one mA when operating from a 5 volt supply, or 3 mA when operating from a 12 volt supply. See the attached data sheet for details.

Duplex, Simplex, +, -, +5 kHz. These offset signals are supplied by 74HC logic gates, capable of sourcing and sinking at least 4 mA. Since all the outputs except +5 kHz have a series diode, these outputs only *source* current. The 47K pulldown resistors provide a DC path to ground for the circuitry in the transceiver. The 74HC08 and 74HC02 supplying these signals *must* operate from a 5 volt supply. If it's necessary to operate at a different supply voltage, replace these with their 74C equivalents.

Control Outputs. The control logic outputs from the fourth shift/store register (U4) are buffered by a Darlington transistor array. U5, a Sprague ULN2804A, is capable of sinking up to 500 mA at each output in the on state, with a total power dissipation for the package not to exceed 2.25 watts. In the off state, each output can withstand up to 50 volts DC. Being Darlington transistors, when in the on state, the DC output voltage will equal one transistor base-emitter voltage plus one collector-emitter saturation voltage. This means that the low voltage will be .7 volts or higher, depending on the load current. The outputs will *not* switch to within a couple of tenths of a volt from ground like a single transistor switch.

U/D. The Up/Down output is intended for use only with ShackMaster and is compatible with the ICOM microphone Up/Down input in its transceivers.

Most Often Asked Questions ... and Answers

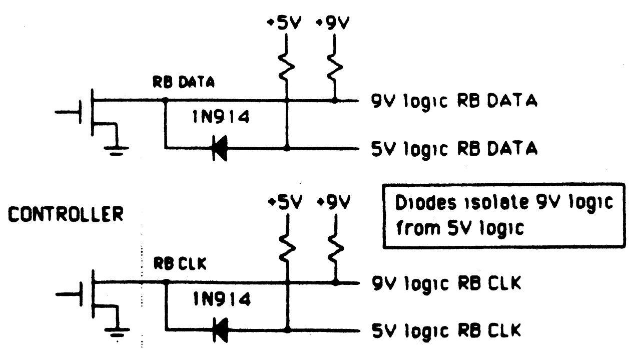
RC-850 Controller Related ...

How can I use two FC-1's on my '850 to control two synthesized remotes?

The two synthesized remotes can be assigned to Link 1 and Link 2 by simply cascading the two FC-1 boards. To do this, connect one board to the controller by connecting Data to the controller's RB DATA and Clk to RB STB (or RB CLK). This first board will respond to Link 1 frequency commands.

Assuming the second board needs to operate at the same supply voltage (because both transceivers operate at the same logic levels), attach its Clk to RB STB as with the first board. Connect its Data to pin 9 of U2 on the first board. This second board will respond to Link 2 frequency commands.

If the boards must operate at different logic levels, such as one at five volts (for an IC-4A, for example), and another at nine volts (for an IC-22U), then the boards can be isolated easily by driving the Data and Clk to the lower supply voltage board through diodes (see below).



How many FC-1 boards are required to recover all 64 user functions from my '850?

Two. Cascade them by connecting the Data input of the second board to pin 9 of U4 on the first board. Clk should drive both boards in parallel. Keep in mind that for this application, it may be more appropriate to build the shift register circuitry independently as shown in the Hardware Reference Manual.

RC-85 Controller Related ...

Does sharing the phone line tie up any of my remote control outputs (UF)?

Yes. The Phone Line Busy Out appears at UF3 (Control Out 6), making it unavailable for general purpose remote control.

If I'm using the RC-85 controller's "glitch-free" mode, where does the remote base or link PTT appear?

It appears at UF8, which is at the pin labeled *Control Out 1.*

ShackMaster Related ...

Can the same FC-1 that is used for the ICOM IC-751 control my secondary rig?

Yes, as long as the secondary rig frequency synthesizer operates at five volts.

How many remote control outputs do I have available with an ICOM IC-751 connected to ShackMaster?

Eight.

General ...

The rig that I would like to use isn't on your list of compatible rigs. What steps should I take to determine whether or not it will interface and function properly?

Understand how the transceiver's frequency synthesizer is controlled. If it's three digit BCD and the offset looks like it can be electronically switched, then chances are you should be able to design the interface logic. The offset signals supplied by the FC-1 board include:

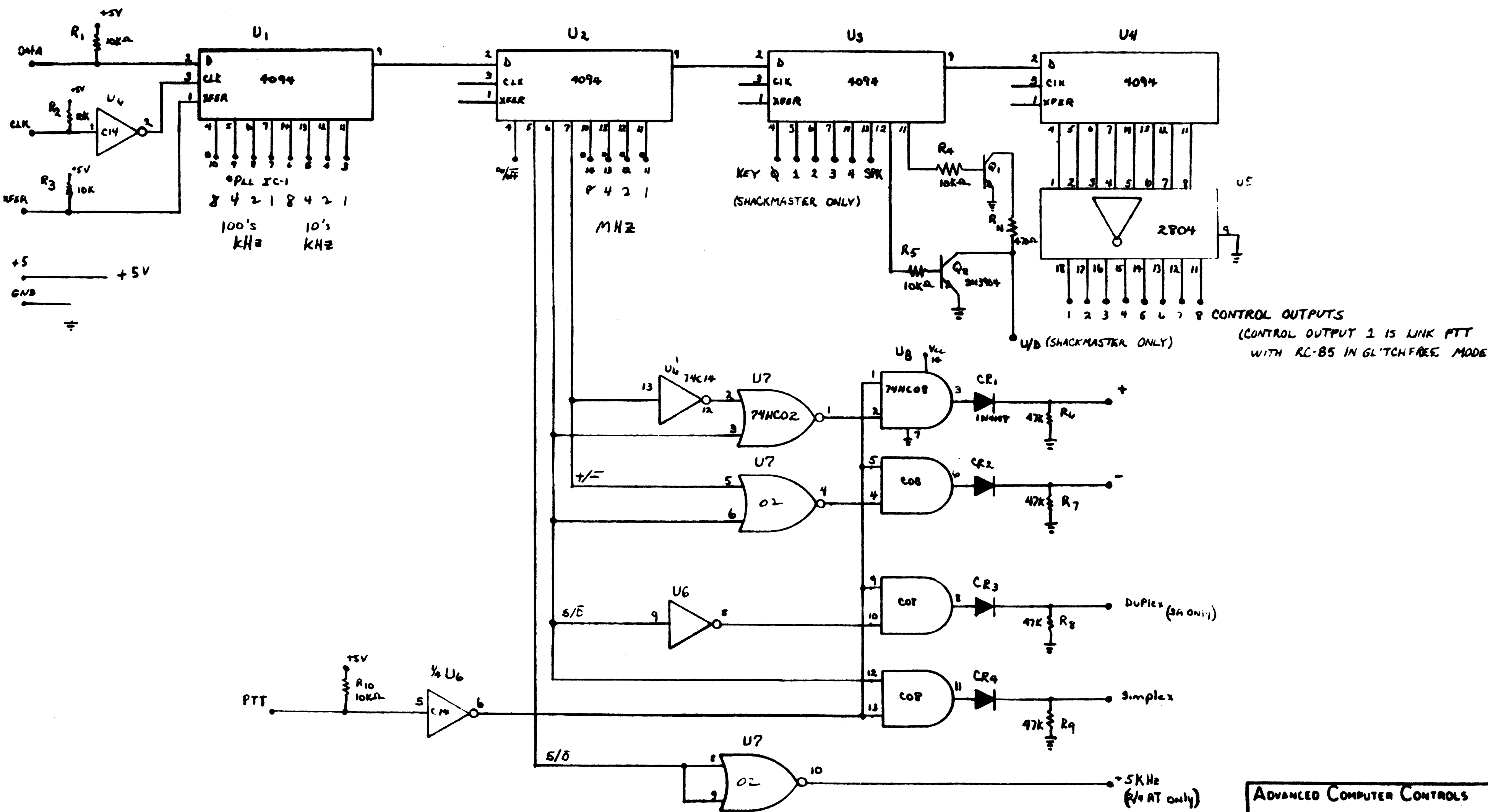
Simplex/Duplex – U2 pin 6. High (+5V etc.) for simplex, low (0V) for duplex.
Plus/Minus Offset – U2 pin 7. High for plus, low for minus.
5 kHz – U2 pin 5. High for +5 kHz, low for 0 kHz. (This is the one's kHz digit.)

Can I control two synthesized transceivers from a single FC-1?

Yes, although only one should be activated at a time. See *ACC Notes,* July/August 1986 for details.

If I convert my FC-1 to work with the ICOM IC-22U, are my remote control outputs (UF) affected in any way?

Not if they're obtained from the Control Output pins. These outputs are open collector. That is, they look either open circuit or like a contact closure to ground. Their operation is independent of the board's power supply voltage.



ADVANCED COMPUTER CONTROLS

DATE 4-84

SCHEMATIC DIAGRAM - FC-1

National Semiconductor

CD4094BM/CD4094BC 8-Bit Shift Register/Latch with TRI-STATE® Outputs

General Description

The CD4094BM/CD4094BC consists of an 8 bit shift register and a TRI-STATE 8-bit latch. Data is shifted serially through the shift register on the positive transition of the clock. The output of the last stage (Q_S) can be used to cascade several devices. Data on the Q_S output is transferred to a second output, Q'_S, on the following negative clock edge.

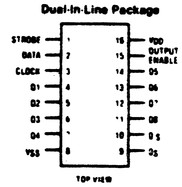
The output of each stage of the shift register feeds a latch, which latches data on the negative edge of the STROBE input. When STROBE is high, data propagates through the latch to TRI-STATE output gates. These gates are enabled when OUTPUT ENABLE is taken high.

Features

- Wide supply voltage range 3.0V to 18V
- High noise immunity 0.45 V_{DD} (typ.)
- Low power TTL compatibility fan out of 2 driving 74L or 1 driving 74LS
- TRI-STATE outputs

Connection Diagram

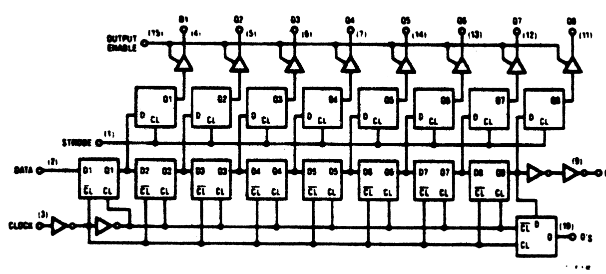
Dual-In-Line Package



Order Number CD4094BMJ or CD4094BCJ
See NS Package J16A

Order Number CD4094BMN or CD4094BCN
See NS Package N16E

Block or Logic Diagram



Absolute Maximum Ratings
(Notes 1 and 2)

V_{DD} Supply Voltage	−0.5 to +18 V_{DC}
V_{IN} Input Voltage	−0.5 to V_{DD} + 0.5 V_{DC}
T_S Storage Temperature Range	−65°C to +150°C
P_D Package Dissipation	500 mW
T_L Lead Temperature (Soldering, 10 seconds)	260°C

Recommended Operating Conditions
(Note 2)

V_{DD} DC Supply Voltage	+3.0 to +15 V_{DC}
V_{IN} Input Voltage	0 to V_{DD} V_{DC}
T_A Operating Temperature Range	
CD4094BM	−55°C to +125°C
CD4094BC	−40°C to +85°C

DC Electrical Characteristics CD4094BM (Note 2)

Sym	Parameter	Conditions	−55°C Min	−55°C Max	25°C Min	25°C Typ	25°C Max	125°C Min	125°C Max	Units
I_{DD}	Quiescent Device Current	V_{DD} = 5.0V		5.0			5.0		150	μA
		V_{DD} = 10V		10			10		300	μA
		V_{DD} = 15V		20			20		600	μA
V_{OL}	Low Level Output Voltage	V_{DD} = 5.0V, I_O < 1.0 μA		0.05		0	0.05		0.05	V
		V_{DD} = 10V		0.05		0	0.05		0.05	V
		V_{DD} = 15V		0.05		0	0.05		0.05	V
V_{OH}	High Level Output Voltage	V_{DD} = 5.0V, I_O < 1 μA	4.95		4.95	5.0		4.95		V
		V_{DD} = 10V	9.95		9.95	10.0		9.95		V
		V_{DD} = 15V	14.95		14.95	15.0		14.95		V
V_{IL}	Low Level Input Voltage	V_{DD} = 5.0V, V_O = 0.5V or 4.5V		1.5			1.5		1.5	V
		V_{DD} = 10V, V_O = 1.0V or 9.0V		3.0			3.0		3.0	V
		V_{DD} = 15V, V_O = 1.5V or 13.5V		4.0			4.0		4.0	V
V_{IH}	High Level Input Voltage	V_{DD} = 5.0V, V_O = 0.5V or 4.5V	3.5		3.5			3.5		V
		V_{DD} = 10V, V_O = 1.0V or 9.0V	7.0		7.0			7.0		V
		V_{DD} = 15V, V_O = 1.5V or 13.5V	11.0		11.0			11.0		V
I_{OL}	Low Level Output Current (Note 3)	V_{DD} = 5.0V, V_O = 0.4V	0.64		0.51	0.88		0.36		mA
		V_{DD} = 10V, V_O = 0.5V	1.6		1.3	2.25		0.9		mA
		V_{DD} = 15V, V_O = 1.5V	4.2		3.4	8.8		2.4		mA
I_{OH}	High Level Output Current (Note 3)	V_{DD} = 5.0V, V_O = 4.6V	−0.64		−0.51	0.88		−0.36		mA
		V_{DD} = 10V, V_O = 9.5V	−1.6		−1.3	2.55		−0.9		mA
		V_{DD} = 15V, V_O = 13.5V	−4.2		−3.4	8.8		−2.4		mA
I_{IN}	Input Current	V_{DD} = 15V, V_{IN} = 0V		−0.1			−0.1		−1.0	μA
		V_{DD} = 15V, V_{IN} = 15V		0.1			0.1		1.0	μA
I_{OZ}	TRI-STATE Output Leakage Current	V_{DD} = 15V, V_{IN} = 0V or 15V		±0.3			±0.3		±9	μA

DC Electrical Characteristics CD4094BC (Note 2)

Sym	Parameter	Conditions	−40°C Min	−40°C Max	25°C Min	25°C Typ	25°C Max	85°C Min	85°C Max	Units
I_{DD}	Quiescent Device Current	V_{DD} = 5.0V		20			20		150	μA
		V_{DD} = 10V		40			40		300	μA
		V_{DD} = 15V		80			80		600	μA
V_{OL}	Low Level Output Voltage	V_{DD} = 5.0V, I_O < 1.0 μA		0.05		0	0.05		0.05	V
		V_{DD} = 10V		0.05		0	0.05		0.05	V
		V_{DD} = 15V		0.05		0	0.05		0.05	V
V_{OH}	High Level Output Voltage	V_{DD} = 5.0V, I_O < 1 μA	4.95		4.95	5.0		4.95		V
		V_{DD} = 10V	9.95		9.95	10.0		9.95		V
		V_{DD} = 15V	14.95		14.95	15.0		14.95		V
V_{IL}	Low Level Input Voltage	V_{DD} = 5.0V, V_O = 0.5V or 4.5V		1.5			1.5		1.5	V
		V_{DD} = 10V, V_O = 1.0V or 9.0V		3.0			3.0		3.0	V
		V_{DD} = 15V, V_O = 1.5V or 13.5V		4.0			4.0		4.0	V
V_{IH}	High Level Input Voltage	V_{DD} = 5.0V, V_O = 0.5V or 4.5V	3.5		3.5			3.5		V
		V_{DD} = 10V, V_O = 1.0V or 9.0V	7.0		7.0			7.0		V
		V_{DD} = 15V, V_O = 1.5V or 13.5V	11.0		11.0			11.0		V
I_{OL}	Low Level Output Current (Note 3)	V_{DD} = 5.0V, V_O = 0.4V	0.52		0.44	0.88		0.36		mA
		V_{DD} = 10V, V_O = 0.5V	1.3		1.1	2.25		0.9		mA
		V_{DD} = 15V, V_O = 1.5V	3.6		3.0	8.8		2.4		mA

DC Electrical Characteristics (cont'd) CD4094BC (Note 2)

Sym	Parameter	Conditions	−40°C Min	−40°C Max	25°C Min	25°C Typ	25°C Max	85°C Min	85°C Max	Units
I_{OH}	High Level Output Current (Note 3)	V_{DD} = 5.0V, V_O = 4.6V	−0.52		−0.44	0.88		−0.36		mA
		V_{DD} = 10V, V_O = 9.5V	−1.3		−1.1	2.55		−0.9		mA
		V_{DD} = 15V, V_O = 13.5V	−3.6		−3.0	8.8		−2.4		mA
I_{IN}	Input Current	V_{DD} = 15V, V_{IN} = 0V		−0.3			−0.3		−1.0	μA
		V_{DD} = 15V, V_{IN} = 15V		0.3			0.3		1.0	μA
I_{OZ}	TRI-STATE Output Leakage Current	V_{DD} = 15V, V_{IN} = 0V or 15V		1			1		10	μA

AC Electrical Characteristics T_A = 25°C, C_L = 50 pF

Symbol	Parameter	Conditions	Min	Typ	Max	Units
t_{PHL}, t_{PLH}	Propagation Delay Clock to Q_S	V_{DD} = 5.0V		300	600	ns
		V_{DD} = 10V		125	250	ns
		V_{DD} = 15V		95	190	ns
t_{PHL}, t_{PLH}	Propagation Delay Clock to Q'_S	V_{DD} = 5.0V		230	460	ns
		V_{DD} = 10V		110	220	ns
		V_{DD} = 15V		75	150	ns
t_{PHL}, t_{PLH}	Propagation Delay Clock to Parallel Out	V_{DD} = 5.0V		420	840	ns
		V_{DD} = 10V		195	390	ns
		V_{DD} = 15V		135	270	ns
t_{PHL}, t_{PLH}	Propagation Delay Strobe to Parallel Out	V_{DD} = 5.0V		290	580	ns
		V_{DD} = 10V		145	290	ns
		V_{DD} = 15V		100	200	ns
t_{PHZ}	Propagation Delay High Level to High Impedance	V_{DD} = 5.0V		140	280	ns
		V_{DD} = 10V		75	150	ns
		V_{DD} = 15V		55	110	ns
t_{PLZ}	Propagation Delay Low Level to High Impedance	V_{DD} = 5.0V		140	280	ns
		V_{DD} = 10V		75	150	ns
		V_{DD} = 15V		55	110	ns
t_{PZH}	Propagation Delay High Impedance to High Level	V_{DD} = 5.0V		140	280	ns
		V_{DD} = 10V		75	150	ns
		V_{DD} = 15V		55	110	ns
t_{PZL}	Propagation Delay High Impedance to Low Level	V_{DD} = 5.0V		140	280	ns
		V_{DD} = 10V		75	150	ns
		V_{DD} = 15V		55	110	ns
t_{THL}, t_{TLH}	Transition Time	V_{DD} = 5.0V		100	200	ns
		V_{DD} = 10V		50	100	ns
		V_{DD} = 15V		40	80	ns
t_{SU}	Set-up Time Data to Clock	V_{DD} = 5.0V	80	40		ns
		V_{DD} = 10V	40	20		ns
		V_{DD} = 15V	20	10		ns
t_r, t_f	Maximum Clock Rise and Fall Time	V_{DD} = 5.0V	1			ms
		V_{DD} = 10V	1			ms
		V_{DD} = 15V	1			ms
t_{PC}	Minimum Clock Pulse Width	V_{DD} = 5.0V	200	100		ns
		V_{DD} = 10V	100	50		ns
		V_{DD} = 15V	83	40		ns
t_{PS}	Minimum Strobe Pulse Width	V_{DD} = 5.0V	200	100		ns
		V_{DD} = 10V	80	40		ns
		V_{DD} = 15V	70	35		ns
f_{MAX}	Maximum Clock Frequency	V_{DD} = 5.0V	1.5	3.0		MHz
		V_{DD} = 10V	3.0	6.0		MHz
		V_{DD} = 15V	4.0	8.0		MHz
C_{IN}	Input Capacitance	Any Input		5.0	7.5	pF

Note 1: "Absolute Maximum Ratings" are those values beyond which the safety of the device cannot be guaranteed, they are not meant to imply that the devices should be operated at these limits. The tables of "Recommended Operating Conditions" and "Electrical Characteristics" provide conditions for actual device operation.

Note 2: V_{SS} = 0V unless otherwise specified.

Note 3: I_{OH} and I_{OL} are tested one output at a time.

Logic Truth Table

Clock	Output Enable	Strobe	Data	Parallel Outputs Q1	Parallel Outputs Q_N	Serial Outputs Q_S*	Serial Outputs Q'_S
↑	0	X	X	Hi-Z	Hi-Z	Q7	No Chg.
↓	0	X	X	Hi-Z	Hi-Z	No Chg.	Q7
↑	1	0	X	No Chg.	No Chg.	Q7	No Chg.
↑	1	1	0	0	Q_N − 1	Q7	No Chg.
↑	1	1	1	1	Q_N − 1	Q7	No Chg.
↓	1	1	1	No Chg.	No Chg.	No Chg.	Q7

X = Don't Care

*At the positive clock edge, information in the 7th shift register stage is transferred to Q8 and Q_S.

MM54HC08/MM74HC08

National Semiconductor

microCMOS

MM54HC08/MM74HC08 Quad 2-Input AND Gate

General Description

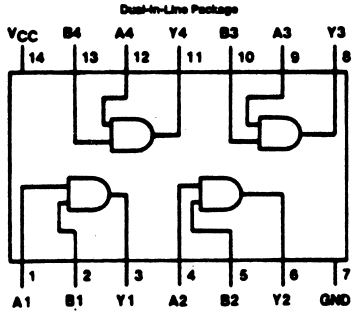
These AND gates utilize microCMOS Technology, 3.5 micron silicon gate P-well CMOS, to achieve operating speeds similar to LS-TTL gates with the low power consumption of standard CMOS integrated circuits. The HC08 has buffered outputs, providing high noise immunity and the ability to drive 10 LS-TTL loads. The 54HC/74HC logic family is functionally as well as pin-out compatible with the standard 54LS/74LS logic family. All inputs are protected from damage due to static discharge by internal diode clamps to V_{CC} and ground.

Features

- Typical propagation delay: 7 ns (t_{PHL}), 12 ns (t_{PLH})
- Fanout of 10 LS-TTL loads
- Quiescent power consumption: 2 μA maximum at room temperature
- Typical input current: 10^{-5} μA

Connection Diagram

Dual-In-Line Package



Top View

Order Number MM54HC08J or MM74HC08J, N
See NS Package J14A or N14A

Absolute Maximum Ratings (Notes 1 & 2)

Supply Voltage (V_{CC})	−0.5 to +7.0V
DC Input Voltage (V_{IN})	−1.5 to V_{CC}+1.5V
DC Output Voltage (V_{OUT})	−0.5 to V_{CC}+0.5V
Clamp Diode Current (I_{IK}, I_{OK})	±20 mA
DC Output Current, per pin (I_{OUT})	±25 mA
DC V_{CC} or GND Current, per pin (I_{CC})	±50 mA
Storage Temperature Range (T_{STG})	−65°C to +150°C
Power Dissipation (P_D) (Note 3)	500 mW
Lead Temp. (T_L) (Soldering 10 seconds)	260°C

Operating Conditions

	Min	Max	Units
Supply Voltage (V_{CC})	2	6	V
DC Input or Output Voltage (V_{IN}, V_{OUT})	0	V_{CC}	V
Operating Temp. Range (T_A)			
MM74HC	−40	+85	°C
MM54HC	−55	+125	°C
Input Rise or Fall Times (t_r, t_f) V_{CC}=2.0V		1000	ns
V_{CC}=4.5V		500	ns
V_{CC}=6.0V		400	ns

DC Electrical Characteristics (Note 4)

Symbol	Parameter	Conditions	V_{CC}	T_A=25°C Typ	T_A=25°C Guaranteed Limits	74HC T_A=−40 to 85°C	54HC T_A=−55 to 125°C	Units
V_{IH}	Minimum High Level Input Voltage		2.0V		1.5	1.5	1.5	V
			4.5V		3.15	3.15	3.15	V
			6.0V		4.2	4.2	4.2	V
V_{IL}	Maximum Low Level Input Voltage		2.0V		0.3	0.3	0.3	V
			4.5V		0.9	0.9	0.9	V
			6.0V		1.2	1.2	1.2	V
V_{OH}	Minimum High Level Output Voltage	$V_{IN}=V_{IH}$ $\|I_{OUT}\| \le 20$ μA	2.0V	2.0	1.9	1.9	1.9	V
			4.5V	4.5	4.4	4.4	4.4	V
			6.0V	6.0	5.9	5.9	5.9	V
		$V_{IN}=V_{IH}$ $\|I_{OUT}\| \le 4.0$ mA	4.5V	4.2	3.98	3.84	3.7	V
		$\|I_{OUT}\| \le 5.2$ mA	6.0V	5.7	5.48	5.34	5.2	V
V_{OL}	Maximum Low Level Output Voltage	$V_{IN}=V_{IH}$ or V_{IL} $\|I_{OUT}\| \le 20$ μA	2.0V	0	0.1	0.1	0.1	V
			4.5V	0	0.1	0.1	0.1	V
			6.0V	0	0.1	0.1	0.1	V
		$V_{IN}=V_{IH}$ or V_{IL} $\|I_{OUT}\| \le 4.0$ mA	4.5V	0.2	0.26	0.33	0.4	V
		$\|I_{OUT}\| \le 5.2$ mA	6.0V	0.2	0.26	0.33	0.4	V
I_{IN}	Maximum Input Current	$V_{IN}=V_{CC}$ or GND	6.0V		±0.1	±1.0	±1.0	μA
I_{CC}	Maximum Quiescent Supply Current	$V_{IN}=V_{CC}$ or GND $I_{OUT}=0$ μA	6.0V		2.0	20	40	μA

Note 1: Absolute Maximum Ratings are those values beyond which damage to the device may occur.

Note 2: Unless otherwise specified all voltages are referenced to ground.

Note 3: Power Dissipation temperature derating — plastic "N" package: −12 mW/°C from 65°C to 85°C; ceramic "J" package: −12 mW/°C from 100°C to 125°C.

Note 4: For a power supply of 5V ±10% the worst case output voltages (V_{OH}, and V_{OL}) occur for HC at 4.5V. Thus the 4.5V values should be used when designing with this supply. Worst case V_{IH} and V_{IL} occur at V_{CC}=5.5V and 4.5V respectively. (The V_{IH} value at 5.5V is 3.85V.) The worst case leakage current (I_{IN}, I_{CC}, and I_{OZ}) occur for CMOS at the higher voltage and so the 6.0V values should be used.

MM54HC08/MM74HC08

3

INTEGRATED POWER SEMICONDUCTORS, LTD.

Darlington Transistor Arrays

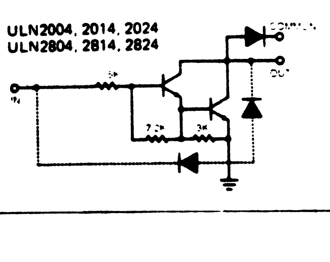
Description

These power driver arrays are an arrangement of either seven (2000 series) or eight (2800 series) darlington transistors with independent inputs and outputs. They are designed to provide a high voltage, medium current interface between low voltage control logic and peripheral loads. The range of inputs available allow specific compatibility with all popular logic families (PMOS, CMOS, TTL, Shottky TTL). Different maximum output current / output voltage combinations allow the customer to select the device closest to the exact needs of the application. Each darlington is configured as an open collector output with internal flyback diode to protect against potentially destructive transient voltages caused by inductive loads.

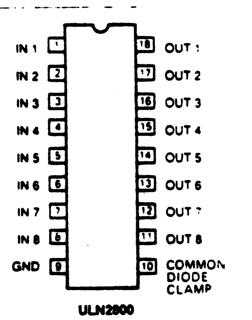
Features

- **7 or 8 darlington power drives in single package**
- **50V or 95V breakdown voltage ratings**
- **500mA or 600mA output current capability per driver**
- **Low saturation voltage**
- **5 input options to allow correct interface with all popular logic families**
- **Internal clamp diodes for driving inductive loads**
- **Improved cross-talk noise suppression**
- **Available in plastic DIP and SOIC packages**

Connections



Top View



Electrical Characteristics

(Unless otherwise indicated, electrical characteristics apply for T_A=25°C only.)

Characteristic	Test Conditions	Device	Min	Typ	Max	Units
Output Leakage Current, I_{CEX}	V_{CE}=50V	All			50	μA
	V_{CE}=50V, T_A=70°				100	μA
	V_{CE}=50V, V_{IN}=6.0V, T_A=70°C	2002, 2802			500	μA
	V_{CE}=50V, V_{IN}=1.0V, T_A=70°C	2004, 2804			500	μA
Collector-Emitter Saturation Voltage, $V_{CE(SAT)}$	I_C=100mA, I_B=250μA	All		0.9	1.1	V
	I_C=200mA, I_B=350μA			1.1	1.3	V
	I_C=350mA, I_B=500μA			1.3	1.6	V
Input Current, $I_{IN(ON)}$	V_{IN}=17V	2002, 2802		0.82	1.25	mA
	V_{IN}=3.85V	2003, 2803		0.93	1.35	mA
	V_{IN}=5.0V	2004, 2804		0.35	0.5	mA
	V_{IN}=12V			1.0	1.45	mA
	V_{IN}=3.0V	2005, 2805		1.5	2.4	mA
Input Current, $I_{IN(OFF)}$	I_C=500μA, T_A=70°C	All	50	65		μA
Input Voltage, $V_{IN(ON)}$	V_{CE}=2.0V, I_C=300mA	2002, 2802			13	V
	V_{CE}=2.0V, I_C=200mA	2003, 2803			2.4	V
	V_{CE}=2.0V, I_C=250mA				2.7	V
	V_{CE}=2.0V, I_C=300mA				3.0	V
	V_{CE}=2.0V, I_C=125mA	2004, 2804			5.0	V
	V_{CE}=2.0V, I_C=200mA				6.0	V
	V_{CE}=2.0V, I_C=275mA				7.0	V
	V_{CE}=2.0V, I_C=350mA				8.0	V
	V_{CE}=2.0V, I_C=350mA	2005, 2805			2.4	V
DC Forward Current Transfer Ratio, h_{FE}	V_{CE}=2.0V, I_C=350mA	2001, 2801	1000			
Input Capacitance, C_{IN}		All		15	25	pF
Turn-on Delay, t_{PLH}	0.5 E_{IN} to 0.5 E_{OUT}	All		0.25	1.0	μs
Turn-off Delay, t_{PHL}	0.5 E_{IN} to 0.5 E_{OUT}	All		0.25	1.0	μs
Clamp Diode Leakage Current, I_R	V_R=50V	All			50	μA
	V_R=50V, T_A=70°C				100	μA
Clamp Diode Forward Voltage, V_F	I_F=350mA	All		1.7	2.0	V

Absolute Maximun Ratings (T_A=25°C)

Output Voltage, V_{CE}
- ULN2000, 2010, 2800, 2810 Series: 50V
- ULN2020, 2820 Series: 95V

Input Voltage, V_{IN}
- ULN2002, 2003, 2004, 2802, 2803, 2804: 30V
- ULN2005, 2805: 15V

Continuous Collector Current, I_C
- ULN2000, 2020, 2800, 2820 Series: 500mA
- ULN2010, 2810 Series: 600mA

Continuous Base Current, I_B: 25mA

Power Dissipation, P_D
- (Single Darlington Drive): 1.0W
- *Total Package ULN2000N: 2.0W
- ULN2000D: 0.96W
- ULN2800N: 2.25W
- ULN2800D: 1.08W

Operating Temperature Range, T_A: -20°C to +85°C

Storage Temperature Range, T_S: -55°C to +150°C

Absolute maximum ratings are those values beyond which the safety of the device cannot be guaranteed. They are not meant to imply that the devices should be operated at these limits. The electrical characteristics provide conditions for actual device operation.