Automatic MEA Coupling Tester: two proposed designs

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Submitted to fulfill partial requirements of HNRS 4900 Special Problems taken under Dr. Günter Gross

Spring 2004
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Acknowledgements

First and foremost, I want to express my gratitude to Dr. Günter Gross, without whose constant direction and advice this project would not have even been possible. Even as this report ‘ends’, our continued project in fact does not, and therein lies my good fortune of getting to know of Dr. Gross through this project.

Over the course of this project, I have had the opportunity to interact and get inputs from individuals related to the fabrication and use of the MEAs. Many thanks are due in particular to Mr. Todd Hall who provided me an ‘orientation’ of sorts by laying out the problem and the expectations involved at the beginning of the project, and Mr. Ahmet Ors, who provided me with extremely helpful inputs and tips multiple times during the past few weeks.
Automatic MEA Coupling Tester

**Objective**

To develop an automatic coupling tester to test for electrode-electrode coupling on an MEA plate.

**Discussion of the Problem**

Coupling (or ‘shorting’) of microelectrodes on an MEA plate can occur in 2 primary ways:

1. Coupling between two consecutive microelectrodes due to a short between the two along their length (fig 1a)

2. Coupling between any two microelectrodes on the MEA plate due to a short connection the two at their end-points in central matrix (fig 1b)

1a. The red lines show some possible couplings between consecutive microelectrodes along their lengths

1b. The red lines show some possible couplings between non-consecutive microelectrodes in the central matrix area

The above diagrams taken and modified from www.cnns.org
While coupling of the first type (henceforth referred to as Type I coupling) is fairly common and is therefore of utmost interest to users, coupling of the second type (henceforth referred to as Type II coupling) has been relatively rare in occurrence, and can therefore practically be ignored by users to a large extent.

I will propose two solutions in this report – the first, a feasibly practical solution for the current 64-channel MEAs to test for only Type I coupling, while the second, a theoretically researched solution to test for both types of coupling in the current MEAs and expandable to test for even the newly proposed 256-channel MEA.

**Need for an Automatic Coupling Tester**

Currently, after MEAs are manufactured, each of the 64 microelectrodes is tested for inter-electrode coupling, manually, one by one. Of course, considering the rarity of Type II coupling, currently only Type I coupling is tested when checking manually.

Without stating, such a process, apart from being exceptionally cumbersome, slows down the manufacturing process by a huge factor. A Type I automatic coupling tester will reduce the process by a factor of at least about 60 (considering a second spent on each electrode-electrode coupling, the total seconds will be 63). If the second, more comprehensive, solution is adopted, it will in fact test for 2016 (64+63+...+1) couplings at one go.
Solution A

This solution primarily tests only for Type I coupling. Instead of a manual testing process, in which a beeper detects a short, the process is automated by using two 40-pin BASIC Stamps, each on one side of the MEA.

The basic principle underlying both the solutions in this report is that if there are two or more microelectrodes are shorted on the MEA, they will all acquire a HIGH voltage (+5V) if any of them is supplied with a HIGH, and therefore in binary terms, if a 1 is given to any microelectrode that is shorted with others, the other microelectrodes too will acquire a 1.
Solution A implements a simple variation of this logic, by using two microelectrodes on each side, and therefore testing 32 microelectrodes on both sides separately. Given below are the Algorithm and the BASIC Code used to program the microcontroller to implement the solution.

**ALGORITHM**

**START**

Step 1. Pins 0-31 of the BASIC Stamp on the left are connected with corresponding microelectrodes on Side 1 of the MEA plate, and Pins 0-31 of the Stamp on the right are connected to Side 2 microelectrodes.

Step 2. Let a variable, $n$ be 0.

Step 3. The Stamp microcontroller on the left gives a HIGH (+5 V) on Pin $n$, and the rest of the pins ($n+1$ to 31) check if any of them detects a HIGH on their corresponding microelectrode. If any of the other microelectrodes are shorted to the one being tested, they too will acquire a HIGH voltage.

Step 4. If a HIGH is found in Step 2, the value of that Pin number and $n$ is outputted. The outputted values display coupled microelectrodes.

Step 5. The value of $n$ is increased by 1 and while $n < 31$, steps 3-4 are repeated.

Step 6. Steps 2-5 are repeated with the Basic Stamp on the right.

**END**
CODE

'${$STAMP BS2}
'${pbasic 2.5}

pin_array VAR Byte(32)
pin_out VAR Byte
pin_in VAR Byte
i VAR Byte
j VAR Byte

GOSUB RESET

FOR pin_out = 0 TO 31
    HIGH pin_out
    i = pin_out + 1
    FOR pin_in = i TO 30
        GOSUB PIN_READ
        IF (pin_array(pin_in) <> 0) THEN
            DEBUG DEC pin_out, " and DEC pin_in, " are coupled.", 13
        ENDIF
    NEXT
GOSUB RESET
NEXT
END

RESET:
    FOR j = 0 TO 31
        LOW j
        INPUT j
    NEXT
RETURN

PIN_READ:
    pin_array(0) = IN0
    pin_array(1) = IN1
    pin_array(2) = IN2
    pin_array(3) = IN3
    pin_array(4) = IN4
    pin_array(5) = IN5
    pin_array(6) = IN6
    pin_array(7) = IN7
    pin_array(8) = IN8
pin_array(9) = IN9
pin_array(10) = IN10
pin_array(11) = IN11
pin_array(12) = IN12
pin_array(13) = IN13
pin_array(14) = IN14
pin_array(15) = IN15
pin_array(16) = IN16
pin_array(17) = IN17
pin_array(18) = IN18
pin_array(19) = IN19
pin_array(20) = IN20
pin_array(21) = IN21
pin_array(22) = IN22
pin_array(23) = IN23
pin_array(24) = IN24
pin_array(25) = IN25
pin_array(26) = IN26
pin_array(27) = IN27
pin_array(28) = IN28
pin_array(29) = IN29
pin_array(30) = IN30
pin_array(31) = IN31

RETURN
Pros

It is the most practical and feasible way we figured to automate the testing system, because the code is small, and there is no extensive external circuit construction required.

It will be cheap in the short term (cost of two BASIC Stamps and related cables).

Cons

The major problem with this approach is that it is inherently unable to test for coupling in the central matrix area, and therefore a small percentage of couplings could go ignored and unrecorded. Note, however, that on either sides individually, it does indeed perform a comprehensive coupling test. For instance if microelectrodes #1 and #15 are coupled inside the matrix area, this solution does catch that (because both 1 and 15 are on the same side), but if say microelectrodes #1 and #45 are coupled, this method will not detect that, since they are on different sides.

A second, less immediate issue with this approach is its inherent expandability problem – if we go beyond 64 channels, then the only solution would be to either get more of such Stamps or re-use the same set multiple times for each 32-channel side.
Solution B

This solution, a theoretically extensive solution, tests comprehensively for both Type I and Type II coupling for all microelectrodes, and is expandable to work for a 256-channel MEA, and can be run by a single Stamp module!

This solution makes use of a Binary Coded Decimal (BCD) decoder to control the output/input on 64 microelectrodes using just two sets of 6 pins (one each for input and output) of the microcontroller. A BCD decoder is a device that converts a binary input into its corresponding decimal equivalent. Thus using a 6-bit BCD, there are $2^6 = 64$ outputs possible, each corresponding to a specific microelectrode in the MEA.

The logic of this solution, though inherently the same, is a bit different structurally, because of the intervention of a BCD controlled input/output system. It too, as Solution A, relies on providing a HIGH on one microelectrode, and checking for a HIGH on the others:

Fig 2a. OUTPUT BCD

Fig 2b. INPUT BCD
One of the major tasks was the evolution of a circuit design to implement the solution. Please see page 14 for the detailed Circuit layout (CAD Printout). The circuit contains, within itself, the two BCDs (6 in / 64 out) and the related circuitry to implement the logic.

Appendix I contains the detailed logic design of our circuit, created in Altera as a Field Programmable Gates Array (FPGA). Also see Appendix II for a theoretical simulation of the model in Altera, and the related observation. The data-sheets for the gates used in the circuit are bunched together as Appendix III.
Step 4. Pin #12 on the microcontroller is connected as the ‘short-detector’. If it
detects a HIGH, output the then value of IJKLMN and ABCDEF. These
two microelectrodes are coupled.

Step 5. Increase ABCDEF by 1 and repeat step 2 until ABCDEF = 111111

END

CODE

'{{$STAMP BS2}}
'{{$pbasic 2.5}}

pin_array VAR Bit (16)
init VAR Nib
z VAR Byte
A VAR Bit: B VAR Bit: C VAR Bit: D VAR Bit: E VAR Bit: F VAR Bit
I VAR Bit: J VAR Bit: K VAR Bit: L VAR Bit: M VAR Bit: N VAR Bit
GOSUB RESET

FOR A = 0 TO 1
  IF (A = 0) THEN
    LOW 0
  ELSE
    HIGH 0
  ENDFI

FOR B = 0 TO 1
  IF (B = 0) THEN
    LOW 1
  ELSE
    HIGH 1
  ENDFI

FOR C = 0 TO 1
  IF (C = 0) THEN
    LOW 2
  ELSE
    HIGH 2
  ENDFI

FOR D = 0 TO 1
  IF (D = 0) THEN
    LOW 3
  ELSE
    HIGH 3
  ENDFI
FOR E = 0 TO 1
    IF (E = 0) THEN
        LOW 4
    ELSE
        HIGH 4
    ENDIF

FOR F = 0 TO 1
    IF (F = 0) THEN
        LOW 5
    ELSE
        HIGH 5
    ENDIF
    init = 0
    GOSUB INPUT_BCD
NEXT
NEXT
NEXT
NEXT
NEXT
NEXT
NEXT
END

INPUT_BCD:
    FOR I = 0 TO 1
        IF (init = 0) THEN
            I = A
        ELSE
            IF (I = 0) THEN
                LOW 6
            ELSE
                HIGH 6
            ENDIF
        ENDIF
    NEXT

    FOR J = 0 TO 1
        IF (init = 0) THEN
            J = B
        ELSE
            IF (J = 0) THEN
                LOW 7
            ELSE
                HIGH 7
            ENDIF
        ENDIF
    NEXT

    FOR K = 0 TO 1
        IF (init = 0) THEN
            K = C
        ELSE
            IF (K = 0) THEN
                LOW 8
            ELSE
                HIGH 8
            ENDIF
        ENDIF
    NEXT
ENDIF
ENDIF

FOR L = 0 TO 1
  IF (init = 0) THEN
    L = D
  ELSE
    IF (L = 0) THEN
      LOW 9
    ELSE
      HIGH 9
    ENDIF
  ENDIF
FOR M = 0 TO 1
  IF (init = 0) THEN
    M = E
  ELSE
    IF (M = 0) THEN
      LOW 10
    ELSE
      HIGH 10
    ENDIF
  ENDIF
FOR N = 0 TO 1
  IF (init = 1) THEN
    init = 2
    IF (I = 0) THEN
      LOW 6
    ELSE
      HIGH 6
    ENDIF
    IF (J = 0) THEN
      LOW 7
    ELSE
      HIGH 7
    ENDIF
    IF (K = 0) THEN
      LOW 8
    ELSE
      HIGH 8
    ENDIF
    IF (L = 0) THEN
      LOW 9
    ELSE
      HIGH 9
    ENDIF
    IF (M = 0) THEN
      LOW 10
    ELSE
      HIGH 10
    ENDIF
  ENDIF
  IF (N = 0) THEN
LOW 11
ELSE
HIGH 11
ENDIF
ELSEIF (init = 0) THEN
  N = F
  init = 1
ELSE
  IF (N = 0) THEN
    LOW 11
  ELSE
    HIGH 11
  ENDIF
ENDIF
GOSUB PIN_READ
IF (pin_array(11) = 1) THEN
  DEBUG 13,DEC A,DEC B,DEC C,DEC D,DEC E,DEC F, "- ",
  DEC I,DEC J,DEC K,DEC L,DEC M,DEC N, "are coupled. "
ENDIF
NEXT
NEXT
NEXT
NEXT
RETURN
RESET:
  FOR z = 0 TO 15
    LOW z
    INPUT z
  NEXT
RETURN

RESET_8_15:
  FOR z = 8 TO 15
    LOW z
    INPUT z
  NEXT
RETURN

PIN_READ:
  pin_array(0) = IN0
  pin_array(1) = IN1
  pin_array(2) = IN2
  pin_array(3) = IN3
  pin_array(4) = IN4
  pin_array(5) = IN5
  pin_array(6) = IN6
  pin_array(7) = IN7
pin_array(8) = IN8
pin_array(9) = IN9
pin_array(10) = IN10
pin_array(11) = IN11
pin_array(12) = IN12
pin_array(13) = IN13
pin_array(14) = IN14
pin_array(15) = IN15
RETURN

The next page has the detailed circuit layout for this model.
Description of Logic gates

The circuit layout that is attached in the previous page consists of the following main components (Datasheets of these gates are attached as Appendix III for component details)

8-input NAND (74F30):

2-input NAND (74F132):

2-input AND (74ALS08)
**Pros**

This solution offers two major advantages, which appear to be comprehensive in solving our coupling problem. The first being that this testing is a thorough checking for all possible coupling combinations – both Type I and Type II.

The second, ostensibly more attractive advantage lies in its potential to be expanded as a testing device for the 256-channel MEA that is being foreseen. That manually checking for coupling in that device would be a bother is an understatement, hence, an automatic tester will be needed for that application, and this solution will stand up to that test.

**Cons**

The only major disadvantage in this solution is the intrinsic complexity in building and troubleshooting such a circuit. However, in my view, that has the potential of being easily resolvable, by giving the design to a PCB manufacturer.

It could appear to be a little more expensive solution in the short run, due to the cost of building the circuit board.
Feasibility Proposal

As discussed with Dr. Gross, I believe the best solution to the problem will be implementing Solution A for the current MEA, to take off the burden for manual testing with immediate result, and to build towards Solution B in consultation with a Circuit Board designer, and to work towards developing impedance-testing capability in the circuit.
Appendix I

Altera BCD Logic Printout/Simulation
Appendix II

Model Simulation

Note: Here pins 0-5 and 9-22 are shorted
When #0 is put on HIGH, #5 also gets a HIGH. Therefore 0-5 are coupled. When #5 is put on HIGH, #0 also gets a HIGH. Therefore 5-0 are coupled. When #9 is put on HIGH, #22 also gets a HIGH. Therefore 9-22 are coupled.
When #22 is put on HIGH, 
#9 also gets a HIGH. 
Therefore 22-9 are coupled.
#36 is put on HIGH, and no other microelectrode gets a HIGH. Therefore, #36 is not coupled to any other microelectrode.
<table>
<thead>
<tr>
<th>Name</th>
<th>270.0us</th>
<th>280.0us</th>
<th>285.0us</th>
<th>290.0us</th>
<th>295.0us</th>
<th>300.0us</th>
<th>305.0us</th>
<th>310.0us</th>
<th>315.0us</th>
<th>320.0us</th>
<th>325.0us</th>
<th>330.0us</th>
<th>335.0us</th>
<th>340.0us</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- A1
- B1
- C1
- D1
- E1
- F1
- A2
- B2
- C2
- D2
- E2
- F2

[O] Short
Appendix III
Data Sheets (first 2 pages of each gate)

74F30
8-Input NAND Gate

General Description
This device contains a single gate, which performs the
logic NAND function.

Ordering Code:

<table>
<thead>
<tr>
<th>Order Number</th>
<th>Package Number</th>
<th>Package Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>74F30SC</td>
<td>M14A</td>
<td>14-Lead Small Outline Integrated Circuit (SOIC), JEDEC MS-012, 0.150&quot; Narrow</td>
</tr>
<tr>
<td>74F30SJ</td>
<td>M14D</td>
<td>14-Lead Small Outline Package (SOOP), EIAJ TYPE II, 5.3mm Wide</td>
</tr>
<tr>
<td>74F30PC</td>
<td>N14A</td>
<td>14-Lead Plastic Dual-In-Line Package (PDIP), JEDEC MS-001, 0.300&quot; Wide</td>
</tr>
</tbody>
</table>

Note 1: Devices also available in Tape and Reel. Specify by appending the letter "X" to the ordering code.

Logic Symbol

Connection Diagram

Unit Loading/Fan Out

Function Table

© 2004 Fairchild Semiconductor Corporation DS009560 www.fairchildsemi.com
Absolute Maximum Ratings

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Min</th>
<th>Max</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storage Temperature</td>
<td>-65°C to +150°C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ambient Temperature under Bias</td>
<td>-55°C to +125°C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Junction Temperature under Bias</td>
<td>-55°C to +150°C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_{CC}$ Pin Potential to Ground Pin</td>
<td>-0.5V to +7.0V</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input Voltage (Note 3)</td>
<td>-0.5V to +7.0V</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input Current (Note 3)</td>
<td>-30 mA to +5.0 mA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Voltage Applied to Output</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard Output</td>
<td>-0.5V to $V_{CC}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3-STATE Output</td>
<td>-0.5V to +5.5V</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current Applied to Output</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>in LOW State (Max)</td>
<td>twice the rated $I_{OL}$ (mA)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Recommended Operating Conditions

- Free Air Ambient Temperature: 0°C to +70°C
- Supply Voltage: +4.5V to +5.5V

Note 2: Absolute maximum ratings are values beyond which the device may be damaged or have its useful life impaired. Functional operation under these conditions is not implied.

Note 2: Either voltage limit or current limit is sufficient to protect inputs.

DC Electrical Characteristics

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>$V_{CC}$</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{IH}$</td>
<td>Input HIGH Voltage</td>
<td>2.0</td>
<td>V</td>
</tr>
<tr>
<td>$V_{IL}$</td>
<td>Input LOW Voltage</td>
<td>0.8</td>
<td>V</td>
</tr>
<tr>
<td>$V_{CD}$</td>
<td>Input Clamp Diode Voltage</td>
<td>-1.2</td>
<td>V Min</td>
</tr>
<tr>
<td>$V_{OH}$</td>
<td>Output HIGH Voltage</td>
<td>2.5</td>
<td>V Min</td>
</tr>
<tr>
<td>$V_{OL}$</td>
<td>Output LOW Voltage</td>
<td>0.5</td>
<td>V Min</td>
</tr>
<tr>
<td>$I_{IH}$</td>
<td>Input HIGH Current</td>
<td>5.0</td>
<td>mA Max</td>
</tr>
<tr>
<td>$I_{IL}$</td>
<td>Input LOW Current</td>
<td>7.0</td>
<td>mA Max</td>
</tr>
<tr>
<td>$I_{LH}$</td>
<td>Output HIGH Leakage Current</td>
<td>5.0</td>
<td>mA Max</td>
</tr>
<tr>
<td>$I_{IO}$</td>
<td>Input Leakage Current Test</td>
<td>4.75</td>
<td>V 0.0</td>
</tr>
<tr>
<td>$I_{OO}$</td>
<td>Output Leakage Circuit Current</td>
<td>3.75</td>
<td>$V_{CC} = 150$ mV</td>
</tr>
<tr>
<td>$I_{OL}$</td>
<td>Output LOW Current</td>
<td>0.5</td>
<td>mA Max</td>
</tr>
<tr>
<td>$I_{OS}$</td>
<td>Output Short-Circuit Current</td>
<td>-60</td>
<td>mA Max</td>
</tr>
<tr>
<td>$I_{CCO}$</td>
<td>Power Supply Current</td>
<td>0.5</td>
<td>mA Max</td>
</tr>
</tbody>
</table>

AC Electrical Characteristics

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>$V_{CC} = 5$ V</th>
<th>$V_{CC} = 9$ V</th>
</tr>
</thead>
<tbody>
<tr>
<td>$t_{PH}$</td>
<td>Propagation Delay</td>
<td>1.0</td>
<td>5.0</td>
</tr>
<tr>
<td>$t_{PL}$</td>
<td>$A_{in} = 0$</td>
<td>1.5</td>
<td>5.5</td>
</tr>
</tbody>
</table>
74F132
Quad 2-Input NAND Schmitt Trigger

General Description
The F132 contains four 2-input NAND gates which accept standard TTL input signals and provide standard TTL output levels. They are capable of transforming slowly changing input signals into sharply defined, jitter-free output signals. In addition, they have a greater noise margin than conventional NAND gates.

Each circuit contains a 2-input Schmitt Trigger followed by level shifting circuitry and a standard FAST™ output structure. The Schmitt Trigger uses positive feedback to effectively speed-up slow input transitions, and provide different input threshold voltages for positive and negative-going transitions. This hysteresis between the positive-going and negative-going input threshold (typically 600 mV) is determined by resistor ratios and is essentially insensitive to temperature and supply voltage variations.

Ordering Code:

<table>
<thead>
<tr>
<th>Order Number</th>
<th>Package Number</th>
<th>Package Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>74F132SC</td>
<td>M14A</td>
<td>14-Lead Small Outline Integrated Circuit (SOIC), JEDEC MS-120, 0.150 Narrow</td>
</tr>
<tr>
<td>74F132SJ</td>
<td>M14D</td>
<td>14-Lead Small Outline Package (SOP), EIAJ TYPE II, 5.3mm Wide</td>
</tr>
<tr>
<td>74F132PC</td>
<td>N14A</td>
<td>14-Lead Plastic Dual-In-Line Package (PDIP), JEDEC MS-001, 0.300 Wide</td>
</tr>
</tbody>
</table>

*Devices also available in Tape and Reel: Specify by appending the suffix letter “X” to the ordering code.*

Logic Symbol

Function Table

<table>
<thead>
<tr>
<th>Pin Names</th>
<th>Description</th>
<th>U.L.</th>
<th>Input L.O.</th>
<th>Output L.O.</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A_0$, $B_0$</td>
<td>Inputs</td>
<td>HIGH/LOW</td>
<td>10/9.0</td>
<td>20 $\mu$A/0.6 mA</td>
</tr>
<tr>
<td>$O_0$</td>
<td>Outputs</td>
<td>50/33.3</td>
<td>$-1$ mA/20 mA</td>
<td></td>
</tr>
</tbody>
</table>

H = HIGH Voltage Level
L = LOW Voltage Level
Absolute Maximum Ratings (Note 1)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storage Temperature</td>
<td>-65°C to +150°C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ambient Temperature under Bias</td>
<td>-55°C to +125°C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Junction Temperature under Bias</td>
<td>-55°C to +150°C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_{CC}$ Pin Potential to Ground Pin</td>
<td>-0.5V to +7.0V</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input Voltage (Note 2)</td>
<td>-0.5V to +7.0V</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input Current (Note 2)</td>
<td>-30 mA to +5.0 mA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Voltage Applied to Output in HIGH State (with $V_{CC} = 0V$)</td>
<td>-0.5V to $V_{CC}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard Output</td>
<td>-0.5V to +5.5V</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3-STATE Output</td>
<td>-0.5V to +5.5V</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current Applied to Output in LOW State (Max)</td>
<td>twice the rated $I_{OL}$ (mA)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ESD Last Passing Voltage (Min)</td>
<td>4000V</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Recommended Operating Conditions

Free Air Ambient Temperature: 0°C to +70°C
Supply Voltage: +4.5V to +5.5V

DC Electrical Characteristics

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{TT}$</td>
<td>Positive-going Threshold</td>
<td>1.5</td>
<td>2.0</td>
<td>V</td>
<td>$V_{CC}$</td>
</tr>
<tr>
<td>$V_{TT}$</td>
<td>Negative-going Threshold</td>
<td>0.7</td>
<td>1.1</td>
<td>V</td>
<td>$V_{CC}$</td>
</tr>
<tr>
<td>$\Delta V_T$</td>
<td>Hysteresis ($V_{TT}^+ - V_{TT}^-$)</td>
<td>0.4</td>
<td>V</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td>$V_{CD}$</td>
<td>Input Clamp Diode Voltage</td>
<td>-1.2</td>
<td>V</td>
<td>Min</td>
<td>$I_{H} = -18$ mA</td>
</tr>
<tr>
<td>$V_{OH}$</td>
<td>Output HIGH Voltage 10% $V_{CC}$</td>
<td>2.5</td>
<td>V</td>
<td>Min</td>
<td>$I_{OH} = 1$ mA</td>
</tr>
<tr>
<td>Voltage</td>
<td>9% $V_{CC}$</td>
<td>2.7</td>
<td>V</td>
<td>Min</td>
<td>$I_{OH} = +1$ mA</td>
</tr>
<tr>
<td>$V_{OL}$</td>
<td>Output LOW Voltage 10% $V_{CC}$</td>
<td>0.5</td>
<td>V</td>
<td>Min</td>
<td>$I_{OL} = 20$ mA</td>
</tr>
<tr>
<td>$I_{IN}$</td>
<td>Input HIGH Current</td>
<td>5.0</td>
<td>$\mu$A</td>
<td>Max</td>
<td>$V_{IN} = 2.7$ V</td>
</tr>
<tr>
<td>$I_{OL}$</td>
<td>Input LOW Current</td>
<td>7.0</td>
<td>$\mu$A</td>
<td>Max</td>
<td>$V_{OL} = 7.0$ V</td>
</tr>
<tr>
<td>$I_{OLH}$</td>
<td>Output HIGH Leakage Current</td>
<td>50</td>
<td>$\mu$A</td>
<td>Max</td>
<td>$V_{OUT} = V_{CC}$</td>
</tr>
<tr>
<td>$I_{OD}$</td>
<td>Input Leakage Test</td>
<td>4.75</td>
<td>V</td>
<td>0.0</td>
<td>$I_{OD} = 1.9$ mA</td>
</tr>
<tr>
<td>$I_{ODH}$</td>
<td>Output Leakage Circuit Current</td>
<td>3.75</td>
<td>$\mu$A</td>
<td>0.0</td>
<td>$V_{ODH} = 150$ mV</td>
</tr>
<tr>
<td>$I_{IL}$</td>
<td>Input LOW Current</td>
<td>-0.8</td>
<td>mA</td>
<td>Max</td>
<td>$V_{IN} = 0.5$ V</td>
</tr>
<tr>
<td>$I_{IS}$</td>
<td>Output Short-Circuit Current</td>
<td>-60</td>
<td>mA</td>
<td>Max</td>
<td>$V_{OUT} = 0$ V</td>
</tr>
<tr>
<td>$I_{PCH}$</td>
<td>Power Supply Current</td>
<td>17.0</td>
<td>mA</td>
<td>Max</td>
<td>$V_{OC} = $HIGH</td>
</tr>
<tr>
<td>$I_{PCL}$</td>
<td>Power Supply Current</td>
<td>18.0</td>
<td>mA</td>
<td>Max</td>
<td>$V_{OC} = $LOW</td>
</tr>
</tbody>
</table>

AC Electrical Characteristics

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>$T_A = +25^\circ$C</th>
<th>$T_A = 0^\circ$C to +70°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{CC} = +5.0V$</td>
<td>$V_{CC} = +5.0V$</td>
<td>$V_{CC} = -6.0V$</td>
<td>$V_{CC} = -6.0V$</td>
</tr>
<tr>
<td>$C_L = 50$ pF</td>
<td>$C_L = 50$ pF</td>
<td>$C_L = 50$ pF</td>
<td>$C_L = 50$ pF</td>
</tr>
<tr>
<td>Min</td>
<td>Typ</td>
<td>Max</td>
<td>Min</td>
</tr>
<tr>
<td>I$P_{DL}$</td>
<td>Propagation Delay</td>
<td>4.0</td>
<td>10.5</td>
</tr>
<tr>
<td>$A_{PL}$, $B_{PL}$ to $C_{PL}$</td>
<td>5.0</td>
<td>12.5</td>
<td>5.0</td>
</tr>
</tbody>
</table>
DM74ALS08
Quad 2-Input AND Gate

General Description
This device contains four independent gates, each of which performs the logic AND function.

Features
- Switching specifications at 50 pF
- Switching specifications guaranteed over full temperature and VCC range
- Advanced oxide-isolated, ion-implanted Schottky TTL process
- Functionally and pin for pin compatible with Schottky and low power Schottky TTL counterpart
- Improved AC performance over Schottky and low power Schottky counterparts

Ordering Code:

<table>
<thead>
<tr>
<th>Order Number</th>
<th>Package Number</th>
<th>Package Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM74ALS08M</td>
<td>M14A</td>
<td>14-Lead Small Outline Integrated Circuit (SOIC), JEDEC MS-012, 0.150 Narrow</td>
</tr>
<tr>
<td>DM74ALS08SJ</td>
<td>M14D</td>
<td>14-Lead Small Outline Package (SOP), EIAJ TYPE II, 5.3mm Wide</td>
</tr>
<tr>
<td>DM74ALS08N</td>
<td>N14A</td>
<td>14-Lead Plastic Dual-in-Line Package (PDIP), JEDEC MS-001, 0.300 Wide</td>
</tr>
</tbody>
</table>

Devices also available in Tape and Reel. Specify by appending the suffix letter "X" to the ordering code.

Connection Diagram

Function Table

\[ Y = AB \]

<table>
<thead>
<tr>
<th>Input</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>L</td>
<td>H</td>
</tr>
<tr>
<td>H</td>
<td>L</td>
</tr>
<tr>
<td>H</td>
<td>H</td>
</tr>
</tbody>
</table>

H = HIGH Logic Level
L = LOW Logic Level
Absolute Maximum Ratings (Note 1)

Supply Voltage 7V
Input Voltage 7V
Operating Free Air Temperature Range 0°C to +70°C
Storage Temperature Range -65°C to +150°C

Typical $R_{JA}$
N Package 89°C/W
M Package 120°C/W

Note 1: 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 tables are not guaranteed at the absolute maximum ratings.

Recommended Operating Conditions

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Min</th>
<th>Nom</th>
<th>Max</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{CC}$</td>
<td>Supply Voltage</td>
<td>4.5</td>
<td>5</td>
<td>5.5</td>
<td>V</td>
</tr>
<tr>
<td>$V_{IH}$</td>
<td>HIGH Level Input Voltage</td>
<td>2</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>$V_{IL}$</td>
<td>LOW Level Input Voltage</td>
<td></td>
<td></td>
<td>0.8</td>
<td>V</td>
</tr>
<tr>
<td>$I_{OL}$</td>
<td>HIGH Level Output Current</td>
<td>-0.4</td>
<td></td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td>$T_A$</td>
<td>LOW Level Output Current</td>
<td>6</td>
<td></td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td>Free Air Operating Temperature</td>
<td>0</td>
<td></td>
<td>70</td>
<td>°C</td>
</tr>
</tbody>
</table>

Electrical Characteristics

over recommended operating free air temperature range. All typical values are measured at $V_{CC} = 5V, T_A = 25°C$.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>$V_{CC} = 4.5V, I_i = -18 mA$</th>
<th>$I_{OH} = -0.4 mA$</th>
<th>$V_{CC} = 4.5V$ to 5.5V</th>
<th>$V_{CC} = 4.5V$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{IC}$</td>
<td>Input Clamp Voltage</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_{CW}$</td>
<td>HIGH Level Output Voltage</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_{OL}$</td>
<td>LOW Level Output Voltage</td>
<td>$V_{CC} = 4.5V$</td>
<td>$I_{OH} = 4 mA$</td>
<td>0.25</td>
<td>0.4</td>
<td>V</td>
</tr>
<tr>
<td>$I_{I}$</td>
<td>Input Current @ Maximum Input Voltage</td>
<td>$V_{CC} = 5.5V, V_{IH} = 7V$</td>
<td>$I_{OH} = 8 mA$</td>
<td>0.35</td>
<td>0.5</td>
<td>V</td>
</tr>
<tr>
<td>$I_{H}$</td>
<td>HIGH Level Input Current</td>
<td>$V_{CC} = 5.5V, V_{IH} = 2.7V$</td>
<td>$I_{OL} = 20$</td>
<td>20</td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td>$I_{L}$</td>
<td>LOW Level Input Current</td>
<td>$V_{CC} = 5.5V, V_{IL} = 0.4V$</td>
<td>$I_{OL} = 0.1$</td>
<td></td>
<td>0.1</td>
<td>mA</td>
</tr>
<tr>
<td>$I_{O}$</td>
<td>Output Drive Current</td>
<td>$V_{CC} = 5.5V$</td>
<td>$V_{O} = 2.35V$</td>
<td>-30</td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td>$I_{OC}$</td>
<td>Supply Current</td>
<td>$V_{CC} = 5.5V$</td>
<td>Outputs HIGH</td>
<td>1.3</td>
<td>2.4</td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Outputs LOW</td>
<td>2.2</td>
<td>4</td>
<td>mA</td>
</tr>
</tbody>
</table>

Switching Characteristics

over recommended operating free air temperature range.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>$V_{CC} = 4.5V$ to 5.5V</th>
<th>$R_L = 500$Ω</th>
<th>$C_L = 50$ pF</th>
<th>$V_{CC}$</th>
<th>$R_L$</th>
<th>$C_L$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$t_{PLH}$</td>
<td>Propagation Delay Time</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4</td>
<td>14</td>
<td>na</td>
</tr>
<tr>
<td></td>
<td>LOW-to-HIGH Level Output</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td>10</td>
<td>na</td>
</tr>
<tr>
<td>$t_{PHL}$</td>
<td>Propagation Delay Time</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td>10</td>
<td>na</td>
</tr>
</tbody>
</table>