Discrete Maths - Digital Logic
Laboratory 3: Full Adder

Assessment Criteria

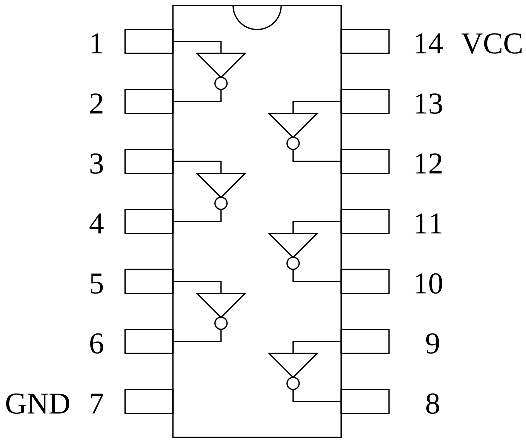
Assessment in this lab is based on these performance measures:

1. Mastery of Boolean Logic;
2. Adherence to Design Principles;
3. Circuit construction;
4. Record of Results;
5. Tidying up after yourself.

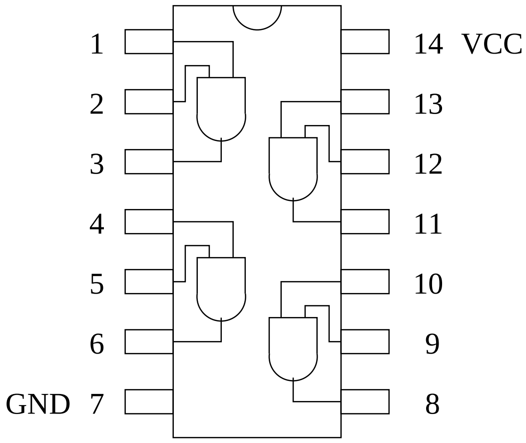
1 Equipment List

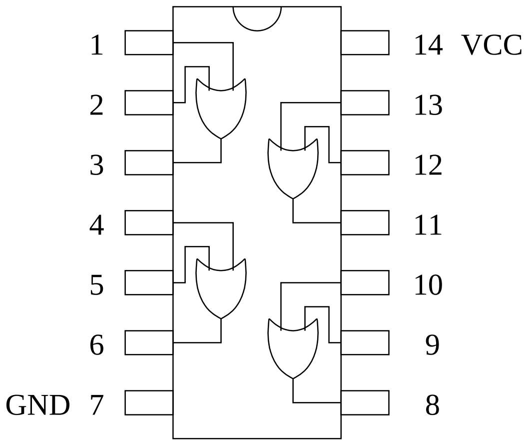
1. 5V power supply
2. Protoboard
3. Switch and LED board
4. Cutters
5. Pliers
6. Single strand hook-up wire
7. One 74LS08 (quad AND)
8. One 74LS86 (quad XOR)

74LS04 HEX NOT

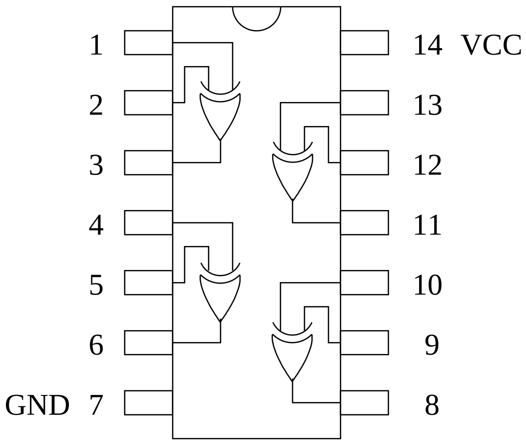


74LS08 QUAD AND



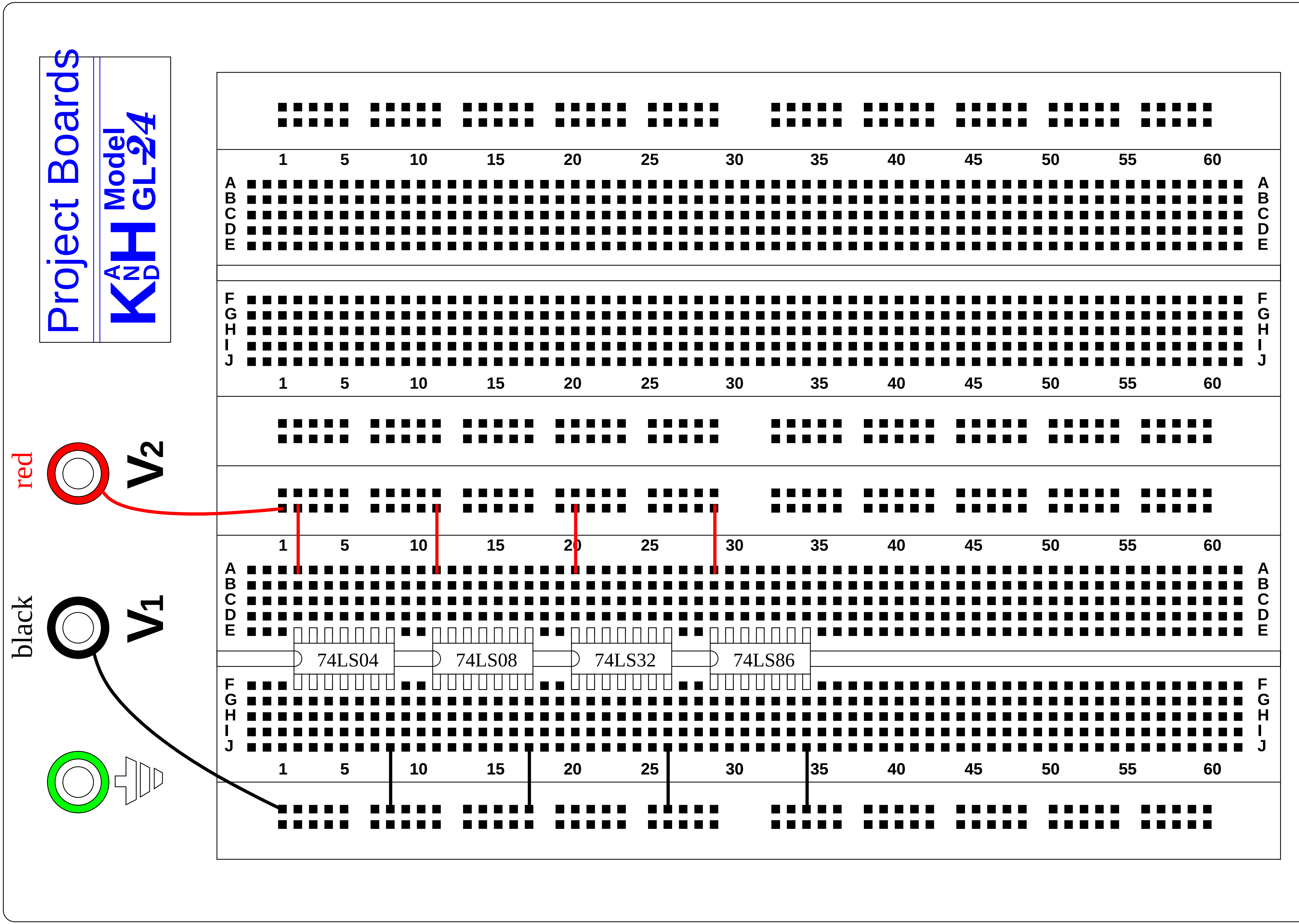


74LS32 QUAD OR



74LS86 QUAD XOR

OVER/


Project Boards
KANDH Model GL-24
red
black
V2
V1
1 5 10 15 20 25 30 35 40 45 50 55 60
A B C D E
F G H I J
74LS04
74LS08
74LS32
74LS86

OVER/

2 Full Adder

The *Half Adder* (HA) of the previous laboratory produces a Carry-Out, but has ***no*** Carry-In, so it can **only** be used to add **1-bit** numbers. In manual decimal arithmetic, each digit is added separately, starting from the least significant digit, and the carry-out from each digit is forwarded as an input to the next higher digit. Similarly, an ***n*-bit binary addition** can be implemented by **cascading** *n Full Adders*. **Each** Full Adder has **three (3) input bits** named **A**, **B** and Carry-In C_i, which it adds together; and **two (2) output bits** named Carry-Out (C_o) and Sum (S) (which together form a **two-bit** number). **Complete the following Truth Table for a Full Adder, *then have it checked and marked by a demonstrator*.**

Hint 1: 0 + 0 + 1 = 1. That has carry out = 0, and sum = 1. Hence, what is **1** as a **2-bit** number?

Hint 2: 1 + 1 + 1 = 3. How is **3** represented in binary? (You NEED to know the binary numbers up to at least **15**, otherwise how will you complete your MAT1DM exam?)

A	B	C_i	C_o	S
0	0	0	***0***	***0***
0	0	1		
0	1	0	***0***	***1***
0	1	1		
1	0	0	***0***	***1***
1	0	1		
1	1	0	***1***	***0***
1	1	1		

In the table, those **output** values for C_o and S that are printed in ***bold italic*** have a carry **input** C_i equal to 0. This ($C_i = 0$) corresponds to the output of a Half Adder. **In the next space, prove this fact mathematically, then *have your answer checked and marked by a demonstrator*.**

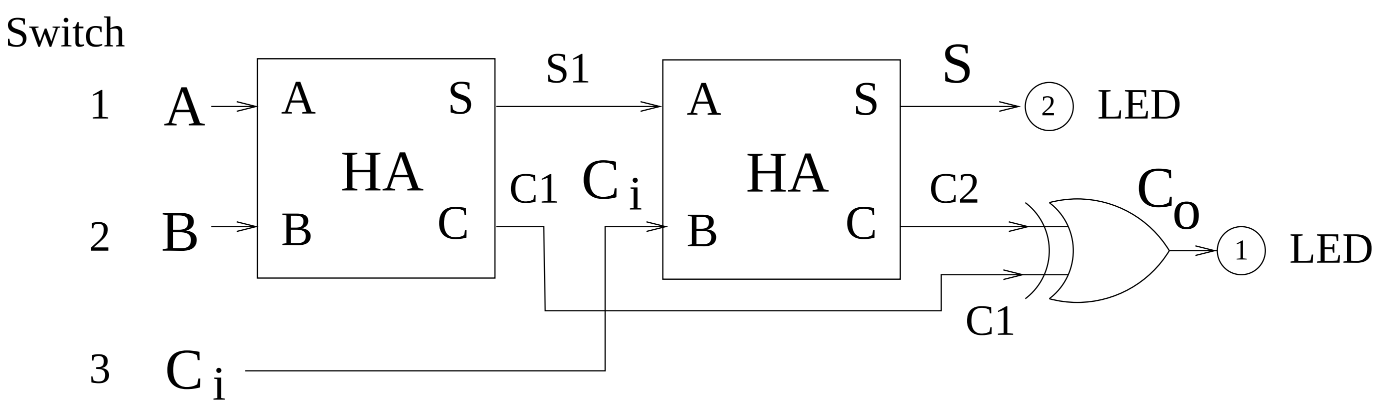
Hint: The formula for a **half adder** is $H = A + B$, and a **full adder** has $F = A + B + C_i$.

Observe that the **S** bit is **1** whenever there are an **odd** number of ones among the inputs A, B and C_i. That means that **S** is the **XOR** of the three inputs: $S = A \oplus B \oplus C_i$. We can implement that as two XORs in series.

Also note that C_o is 1 whenever **at least two** of the inputs are 1. We could implement that using three AND gates and an OR, so that the Full Adder would use six gates altogether, but there's a more efficient solution.

Since $F = A + B + C_i = (A + B) + C_i$ one Half Adder can do the $A + B$ part of the addition, as noted above. We can use a second HA to add C_i to get the full adder's sum bit S. How to obtain its carry-out bit C_o? On a moment's reflection, $C_o = 1$ when either HA has a carry-out. So one might consider using an OR gate to generate C_o.

But can *both* Half Adders produce a *carry* at the *same time*? The first HA produces a carry C1 = 1 when both A and B are 1, and then its sum S1 = 0 and the second HA's carry bit C2 = 0. Therefore the OR gate can be replaced by an **XOR**, so **two** (2) **ICs** suffice, a **74LS08** quad AND and a **74LS86** quad XOR.



There are 8 signals: **3 inputs** A, B and C_i to connect to switches; **3 intermediate signals** S1, C1, C2; and **2 outputs** $C_o$and S, to be connected to LEDs. Fill out the following signal/switch/LED/color table. Remember: **one color for each signal; one signal for each color.**

Signal	Switch	LED	Color
A		none	
B		none	
C_i		none	
S1	none	none	
C1	none	none	
C2	none	none	
C_o	none		
S	none		

This table MUST be approved and MARKED by a demonstrator before you can proceed.

Draw the full design of this circuit, using two AND gates and three XOR gates, in the space provided. You MUST **number all pins**, not only in this diagram, but in every logic diagram in these labs. You also also **MUST** record the **switch** numbers, **LED** numbers, and wire **colors** on the logic diagram.

DO NOT build *anything* yet!

This design MUST be approved and MARKED by a demonstrator before you can proceed.

Abiding by the approved color coding scheme, you may now build the full adder circuit, using one 74LS08 and one 74LS86.

The demonstrators will **NOT** diagnose — much less repair — faults in a circuit that is not wisely color-coded, because it's unreasonable to expect anyone to spend disproportionate time on fixing someone else's poorly constructed circuit.

You have been warned. So build each circuit sensibly.

Have your circuit construction checked and MARKED by a demonstrator.

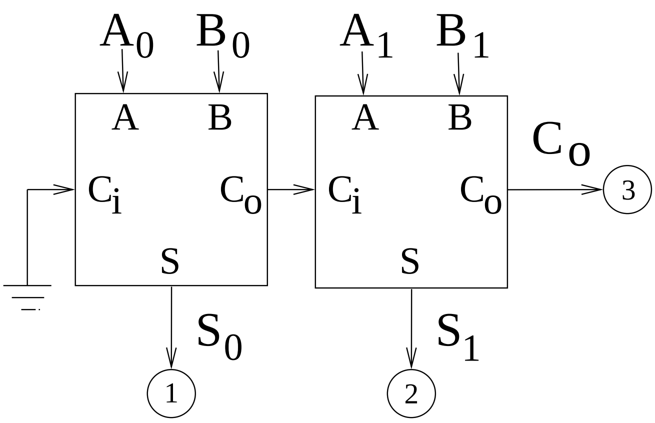
Test the full adder, and record its observed outputs in the following truth table.

1	2	3	*1*	*2*
A	B	C_i	C_o	S
0	0	0		
0	0	1		
0	1	0		
0	1	1		
1	0	0		
1	0	1		
1	1	0		
1	1	1		

These results absolutely MUST be checked and MARKED by a demonstrator before you proceed.

3 Two-Bit Adder

A two-bit adder can be constructed from two full adders, by *joining a wire* from the carry-out of one full adder to the carry-in of the other. Be careful to *remove* the wire that was used to connect a switch to the second full adder's Carry-In. **Combine your full adder with that of a neighboring group to construct this circuit:**



You MUST get the 2-bit adder construction checked and MARKED by a demonstrator before proceeding.

Test the two-bit adder, and record the observed results in the next truth table. (*Warning*: **Pay close attention to the order of the bits.**)

1	2	1	2	*3*	*2*	*1*
A_1	B_1	A_0	B_0	C_0	S_1	S_0
0	0	0	0			
0	0	0	1			
0	0	1	0			
0	0	1	1			
0	1	0	0			
0	1	0	1			
0	1	1	0			
0	1	1	1			
1	0	0	0			
1	0	0	1			
1	0	1	0			
1	0	1	1			
1	1	0	0			
1	1	0	1			
1	1	1	0			
1	1	1	1			

These results MUST be checked and MARKED by a demonstrator, so keep the circuit INTACT until you have the mark for it.

4 Clean Up

LEAVE all **equipment** (board, components, and tools) **on your bench**.

Please **return** every **cord** to the racks, every **wire** to the recycle bin.

Clean the bench **and the carpet**, and place your **chair under the bench**.

Have your **clean-up** ***checked and SIGNED for by a demonstrator***.

Hand in your completion sheet.

2007 Sep 14 Fri 12:24 Geoffrey Tobin