# The Atlas B Adder (Full Parallel Adder)

The B Adder is a parallel type adder and to illustrate the method of operation it is only necessary to consider the action of the circuit on one pair of input digits (x and y) and the effect of the "carry" or "no carry" from the addition of other digits in other circuits.

The information on the x and y inputs to the adder is in the form of 24 address bits or the contents of a B register again 24 bits, each digit being at the inputs to the various Adder Input Boards simultaneously.

The boards used to form the complete adder are as follows:-

| | |
|---|---|
| Type 813 | Adder Input Board |
| Type 812 | Carry Board |
| Type 814 | Adder Output Board |

Diagram 1 shows the logic of each board and the manner in which one set of boards (a section of one set) is inter-connected.

The facilities offered by the adder are, addition (x+y): subtraction (x-y) and reverse subtraction (y-x).

Five signals are taken from the Adder Input Board and used to control the operation of the Carry Board and Adder Output Boards.

The parallel adder is to be presented with the numbers to be added, simultaneously, adds each pair of digits as a separate unit, and produces a carry, if necessary, to be available <u>instantly</u> as an effect in the next circuit where the next pair of digits are being summed. The process is repeated for each pair of digits in the numbers being added.

In order to follow the operation of the adder, it is necessary to know the voltage levels produced in the different circuits.

They are as follows:

Outputs from the Adder Input Board:

| | | | |
|---|---|---|---|
| TA | (TBA) | to Carry Board | '0' ≡ +3.0V |
| TB | (TBB) | | '1' ≡ -ve potential |
| TC | (TBC) | | |
| A | (+ab) | to Adder Output Board | '0' ≡ +2.0V |
| $\overline{A}$ | (+ab-) | | '1' ≡ -0.5V |

Outputs from Carry Board

C carry from previous circuit '0' ≡+1.8V
'1' ≡+0.3V

C' carry produced by current addition '0' ≡ +1.8V
'1' ≡ +0.3V

Adder Output Board

A current of 9mA switched in the output circuit represents a '0' level at the output S.

A current of 1mA switched in the output circuit represents a '1' level at the output S.

S '0' ≡ +2.0V
'1' ≡ -0.5V

These are standard Atlas levels for '0' and '1'

## Operation

Reference should be made to Diagram 1.

Assume both x and y to be '1s' and that the mode of operation is addition.

The gates at the input will be strobed by 'add' and it follows (since the gates are negative 'ands' followed by negative 'ors') that the only gates producing an output will be A, E and F.

The outputs from this board (813) will be:

TA ≡ 0 TB ≡ 1 TC ≡ 0
$\overline{A}$ ≡ 1 A ≡ 0

The first three control the carry circuits and the latter two the Adder Output Board.

The addition of x and y where x = y = 1 must produce a zero in the sum (s) output circuit and must also propogate a carry into the next circuit instantly.

Carry Board

As stated above, TA, TB and TC control the action of the carry circuits. The effect of a negative voltage at the base circuit pins i.e. pins 12, 13, 14 is to 'clamp' the emitter at the potential of the collector. It will be noticed that each transistor TR5 and TR7 has a different 'clamp' potential +1.8V and +0.3V respectively, these representing 'carry 0' and 'carry 1' respectively. The clamp level of TR6 depends upon the presence of a carry or not in the previous circuit and therefore it is possible to allow this carry into the circuit providing TBA goes negative.

On diagram 1, these transistors are represented by switches which will be closed when a negative voltage is applied from the Adder Input Board.

The first section of the first Carry Board is a special circuit which allows the different facilites.

On addition and subtraction (Normal ±), TR1 emitter is held at +18 V which represents a '0', both TR2 and TR3 are held off thus, the first pair of digits for addition can only be presented with a carry = 0.

On reverse subtraction a similar process is carried out, but in this case TR3 is switched on and produces a carry = 1 which is available to the next circuit providing TA is negative.

In the case being considered therefore, the previous carry = 0 and TA = 0 (+3.0V)
TB = 1 (-ve potential)
TC = 0 (+3.0V)

The action of these levels on the carry circuit is to switch on TR7, since TB is applied to this circuit. The remaining transistors remain off. This produces a '1' level on the C' line which forms the carry to the next circuit and also after being applied to an emitter follower becomes a level controlling the Adder Output circuit.

There are six identical circuits per carry board.

## Adder Output

The inputs to this board are A $\bar{A}$ and C'. C' is equivalent to 1 is explained in the last paragraph.

The $\bar{A}$ input is used on addition and subtraction. The selection of these inputs is determined by two strobes:- st(x-y) for subtraction and st(x+y) for addition and reverse subtraction.

The input levels effectively control the switching of two constant current sources which are able to supply either 1mA or 9mA to the output circuits. The latter current is the total when both sources are available. The levels represented by 1mA and 9mA respectively, at the output, are 0 and 1.

The transistor circuit is shown on Diagram 3. The transistors are represented by switches on the logic diagram (diagram 1).

In the example taken, $\bar{A}$ is equivalent to a 1 level and by reference to the switching bay on diagram 1, it will be seen that 8mA is switched into the left hand circuit.

The carry C' from the previous carry circuit, is '0', i.e +1.8V and the two "switches" will be in such a position that 9mA is switched to the S output circuitry producing a rise in potential which is level changed to the standard level for '0' at the output 'S'.

Thus, the circuits have produced a 'carry' to the next section and the result of addition is 0 where x=y=1 at the input.

A truth table can be drawn up, assuming the four possible combinations of x and y and assuming either a 0 or 1 state for the previous carry. In this way all possible results may be tabulated.

Tables for addition, subtraction and reverse subtraction are shown in diagrams 4, 5 and 6 respectively.

By inspection of these tables, certain constants can be deduced.

<u>Addition</u>

The outputs TBA, TBB, TBC can be represented by the following:-

TBA always gives the same result as non-equivalent x with y e.g. when x = y = 0 : TA = 0
when x = 1 and y = 0 : TA = 1

Thus, TA can be said to be represented by $(x \not\equiv y)$. Similar deductions can be made for TB and TC, except that TB produces the same result as collating x and y, i.e. TB = (x&y), and TC gives the same result as collating $\bar{x}$ and $\bar{y}$ i.e. TC = $(\bar{x}\&\bar{y})$.

From this it follows that $\bar{A}$ being the out of phase version of TA is equivalent to $(x \equiv y)$, i.e. when x = y then $\bar{A}$ = 1.

The inputs to the Adder Output can be said to be $(x \equiv y)$ and $(x \not\equiv y)$ respectively, the former being used on addition which means that whenever x = y the adder input is 1, and 0 in the other cases. The carry can also be related to the inputs.

From these ideas a relationship between the conditions of x and y and the carry c' can be shown to hold.

These relationships are as follows (refer to diagram 4):-

When $\bar{x}$ & $\bar{y}$ = 1    c' = 0
$x$ & $y$ = 1    c' = 1
$x \not\equiv y$    c' = c

## Subtraction

Different strobes are used on adder input and adder o output boards, but a truth table can be made up on the same principles as for addition.

Diagram 5 shows the truth table.

The relationships are:-

When $x \,\&\, \bar{y} = 1$ $b' = 0$

$\bar{x} \,\&\, y = 1$ $b' = 1$

$x \equiv y$ $b' = B$

$b'$ being the future borrow

B being the previous borrow.

## Reverse subtraction

The strobes are the normal addition strobes, but in this case the first circuit of the first carry board produces a 1 level. Thus a 1 level controls the first Adder output and is a constant level. c' remains under the control of TA, TB and TC. Again a similar process as in addition and subtraction will produce a truth table which will reveal the following relationships upon inspection:-

When $x \,\&\, \bar{y} = 1$ $b' = 1$

$\bar{x} \,\&\, y = 1$ $b' = 0$

$x = y$ $b' = B$

## Control Adder (Half Adder)

Refer to diagram 7.

The Control Half Adder consists of three different types of board, namely:-

Type 811 Adder Input

Type 812 Carry Board

Type 814 Adder Output

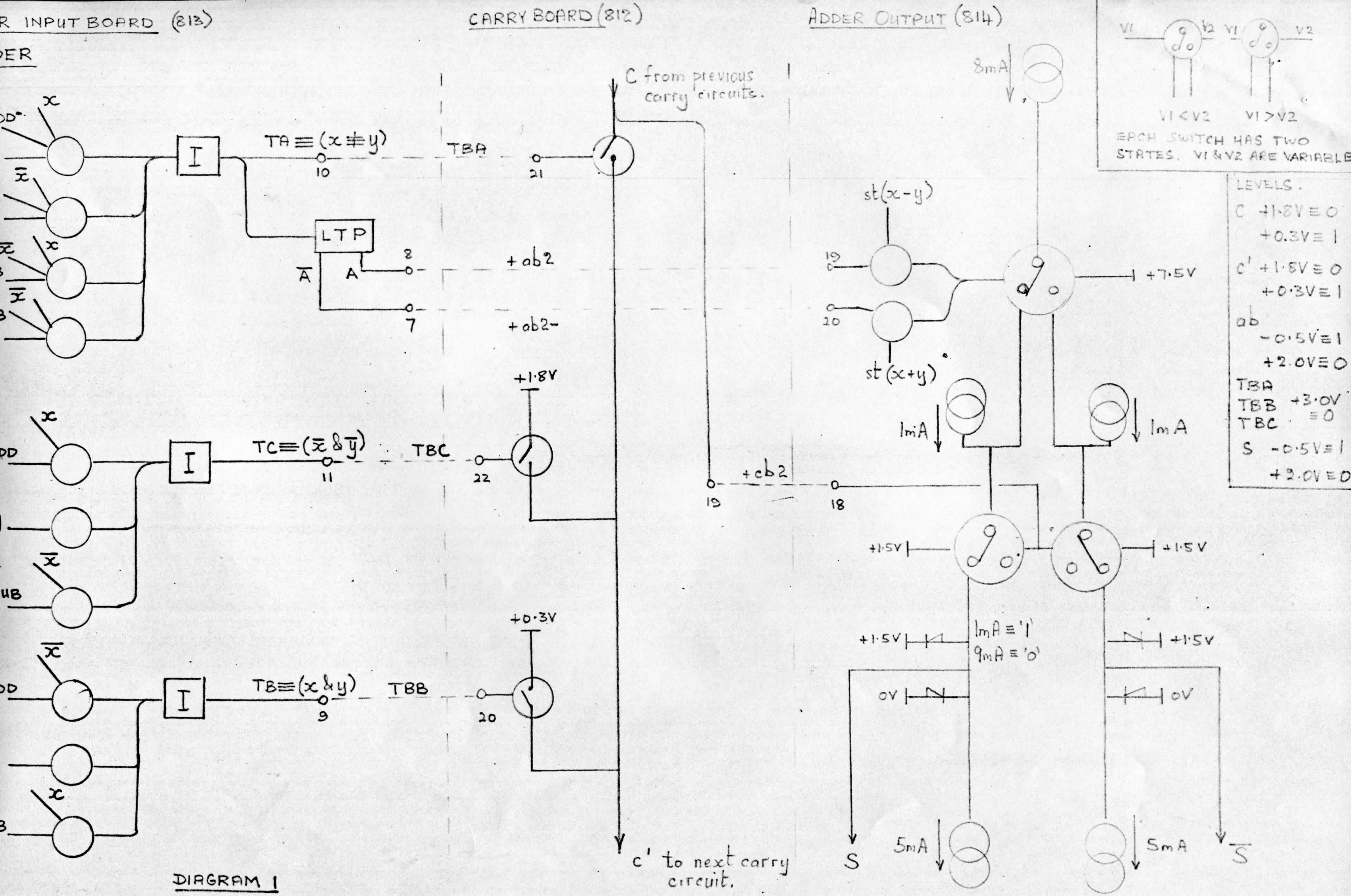
The latter two operate in exactly the same way as seecribed for the B Adder circuit.

The first section of the Carry Board, in this case, produces a level (+0.3V) equivalent to "all 1's". Therefore this is the constant potential controlling the two "switches" in the 1st Adder Output circuit. The +0.3V level control "switch" in the carry section is permanently held off, i.e. only two inputs are required. They are TA and TC and the Adder Input produces these waveforms. (TB is replaced by the +0.3V described above). There is no y input to this adder.

The digit in position AK3 (least significant digit of the address) controls the adder output board. The carry i input to this circuit is permanently +0.3V. The effect of these controls is to produce a carry if AK is a 1 and no carry if AK is 0. The sum digit will be 0 and 1 respectively.

All other circuits i.e. Carry Boards and Adder Outputs then operate as described for the B adder.

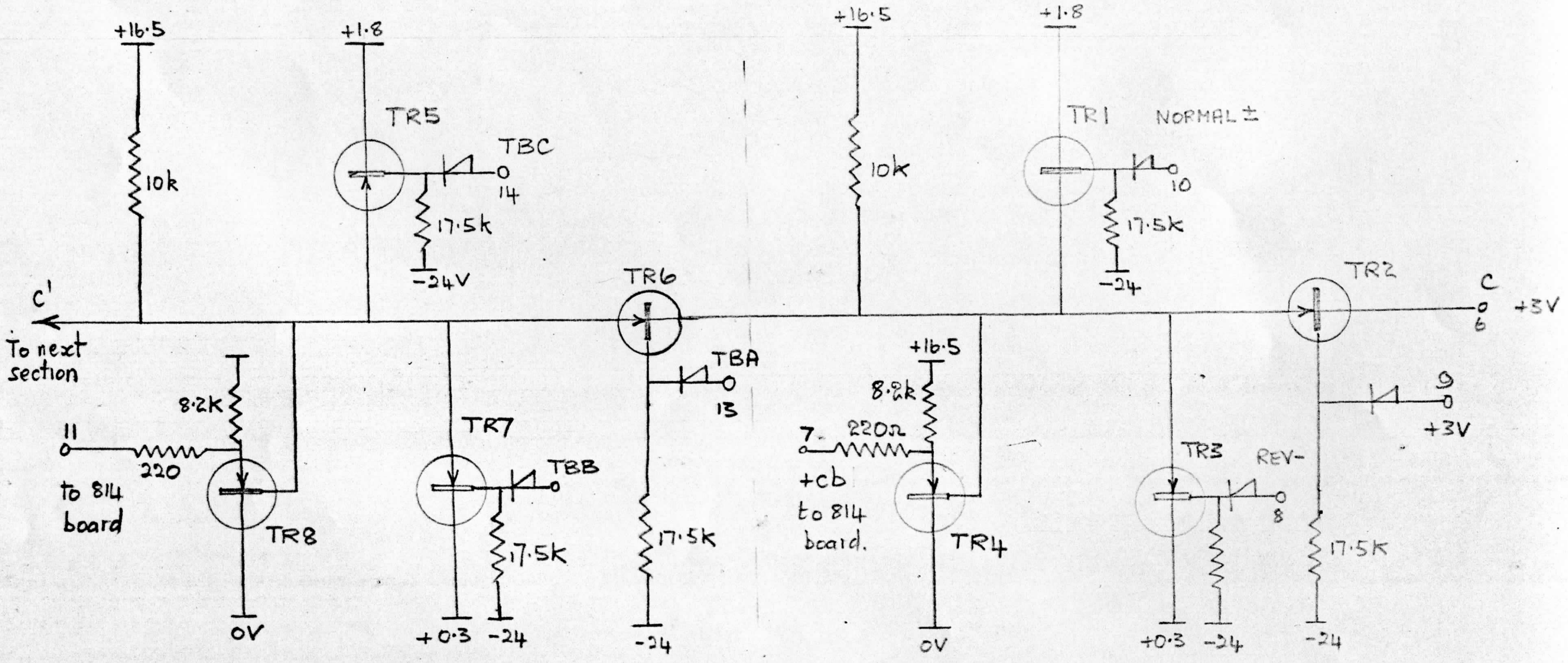
A truth table is shown in diagram 9.



R INPUT BOARD (813)
DER
CARRY BOARD (812)
ADDER OUTPUT (814)
TA≡(x≢y)
TBA
LTP
A
+ab2
+ab2-
TC≡(x̄&ȳ)
TBC
+1·8V
TB≡(x&y)
TBB
+0·3V
C from previous carry circuits.
c' to next carry circuit.
+cb2
st(x-y)
st(x+y)
+7·5V
8mA
1mA
+1·5V
1mA≡'1'
9mA≡'0'
0V
5mA
S
S̄
V1 V2
V1<V2
V1>V2
EACH SWITCH HAS TWO STATES. V1 & V2 ARE VARIABLE
LEVELS.
C +1·8V≡0
+0.3V≡1
c' +1·8V≡0
+0·3V≡1
ab
-0·5V≡1
+2.0V≡0
TBA
TBB +3·0V
TBC ≡0
S -0·5V≡1
+2·0V≡0


DIAGRAM 1

CARRY BOARD (6 IDENTICAL SECTIONS) 812




ADDITION
SUBTRACTION } NORMAL ±

REVERSE SUBTRACTION REV −

DIAGRAM 2

ADDER OUTPUT CIRCUIT

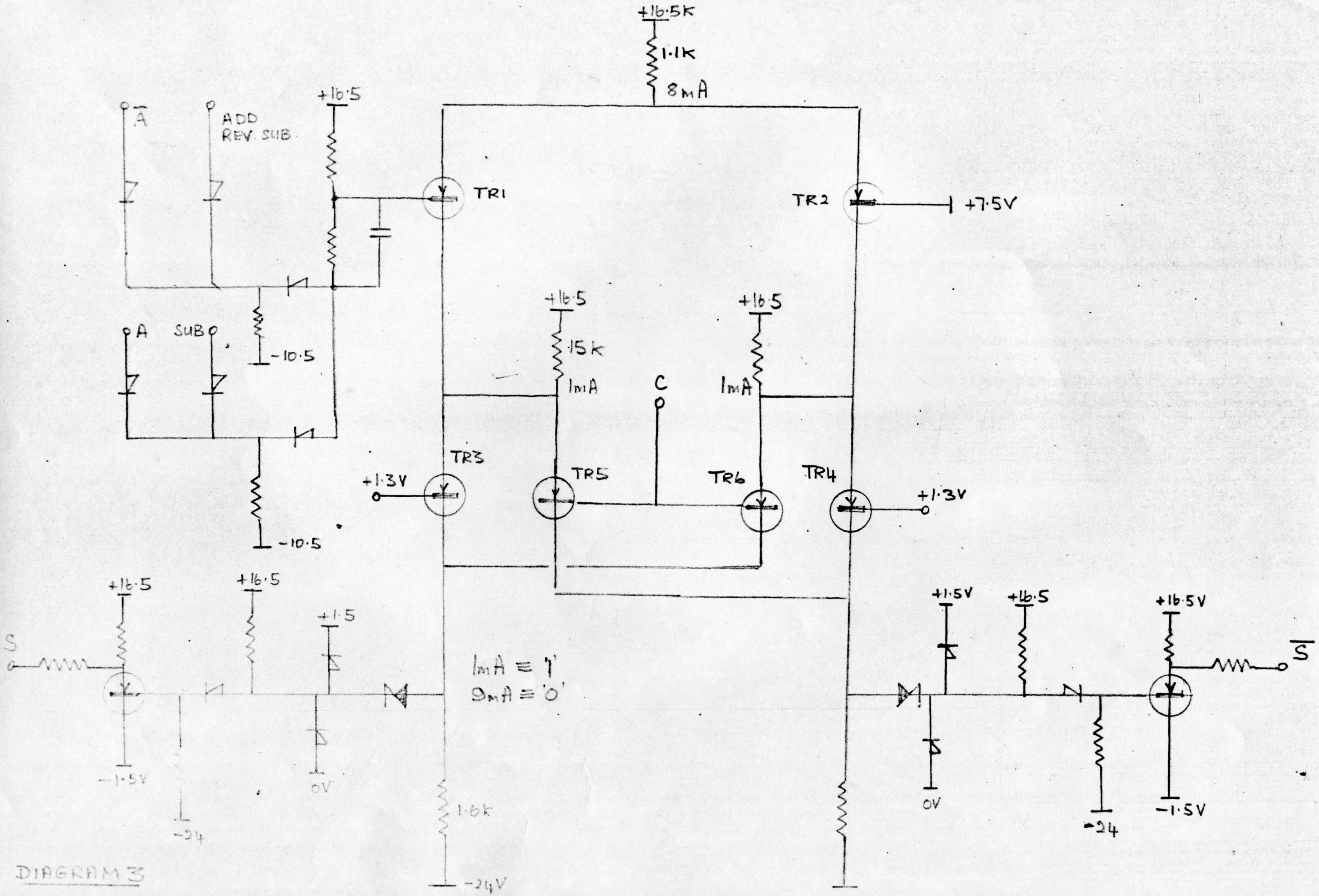



DIAGRAM 3

## ADDITION B ADDER

**CARRY BOARD** (812) **ADDER O/P** (814)

(813) **ADDER INPUT BOARD (OUTPUTS)**

| x | y | ($x \not\equiv y$) TBA | ($x \& y$) TBB | ($\bar{x} \& \bar{y}$) TBC | ($x \not\equiv y$) A | ($x \equiv y$) $\bar{A}$ | Assume C | Then C' | S | ∴ when | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | $\bar{x} \& \bar{y} = 1$ | c' = 0 |
| 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | $x \not\equiv y$ | c' = C |
| 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | $x \not\equiv y$ | c' = C |
| 1 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | $x \& y = 1$ | c' = 1 |
| 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | $\bar{x} \& \bar{y} = 1$ | c' = 0 |
| 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | $x \not\equiv y$ | c' = C |
| 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | $x \not\equiv y$ | c' = C |
| 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | $x \& y = 1$ | c' = 1 |

Rules for adder: ADDITION

| | |
|---|---|
| If $x \ \& \ y = 1$ | c' = 1 |
| $\bar{x} \ \& \ \bar{y} = 1$ | c' = 0 |
| $x \not\equiv y$ | c' = C |

Diagram 4

## SUBTRACTION: B ADDER

(813) ADDER I/P BOARD (OUTPUTS) CARRY BOARD (812) ADDER O/P (814)

| | | $(x \equiv y)$ | $(\bar{x}\&y)$ | $(x\&\bar{y})$ | $(x \equiv y)$ | $(x \not\equiv y)$ | Assume | Then | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| x | y | TBA | TBB | TBC | A | $\bar{A}$ | B | b' | Difference | when | |
| 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | $x \equiv y$ | b'=B |
| 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | $\bar{x}\&y=1$ | b'=1 |
| 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | $x\&\bar{y}=1$ | b'=0 |
| 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | $x \equiv y$ | b'=B |
| 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | $x \equiv y$ | b'=B |
| 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | $\bar{x}\&y=1$ | b'=1 |
| 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | $x\&\bar{y}=1$ | b'=0 |
| 1 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | $x \equiv y$ | b'=B |

Rules for adder: subtraction

$x \& \bar{y} = 1$ b' = 0

$\bar{x} \& y = 1$ b' = 1

$x \equiv y$ b' = B

Diagram 5.

**Reverse Subtraction: B Adder**

| x | y | $(x \equiv y)$ TBA | $(\bar{x} \& y)$ TBB | $(x \& \bar{y})$ TBC | $(x \equiv y)$ A | $(x \neq y)$ $\bar{A}$ | B | b' | Difference | ∴ when | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | $x \equiv y$ | $b' = B$ |
| 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | $\bar{x} \& y = 1$ | $b' = 0$ |
| 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | $x \& \bar{y} = 1$ | $b' = 1$ |
| 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | $x \equiv y$ | $b' = B$ |
| 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | $x \equiv y$ | $b' = B$ |
| 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | $\bar{x} \& y = 1$ | $b' = 0$ |
| 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | $x \& \bar{y} = 1$ | $b' = 1$ |
| 1 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | $x \equiv y$ | $b' = B$ |

**Rules**

If $x \& \bar{y} = 1$ $\quad b' = 1$

$\bar{x} \& y = 1$ $\quad b' = 0$

$x \equiv y$ $\quad b' = B$

Diagram 6

CONNECTIONS. HALF-ADDER

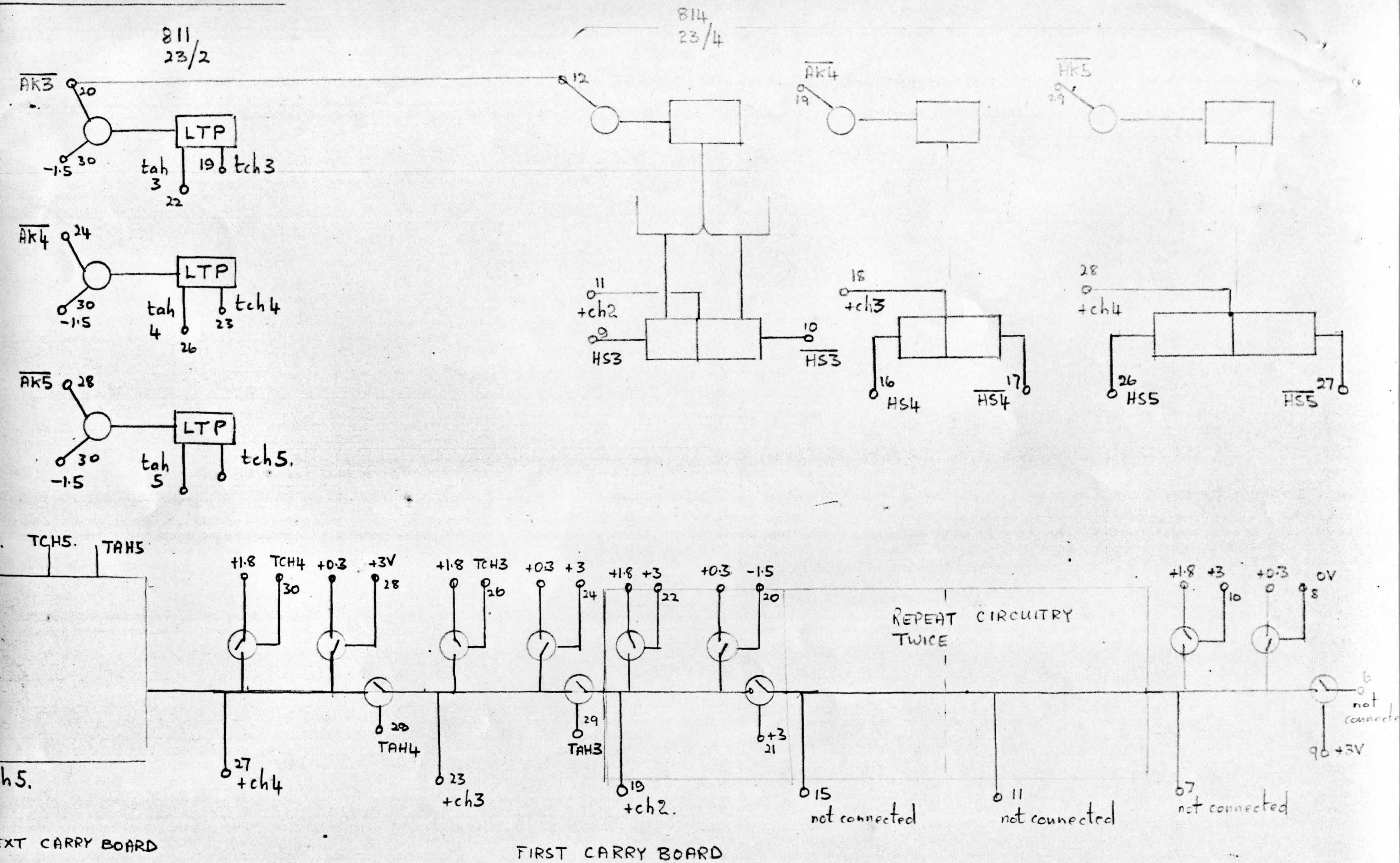
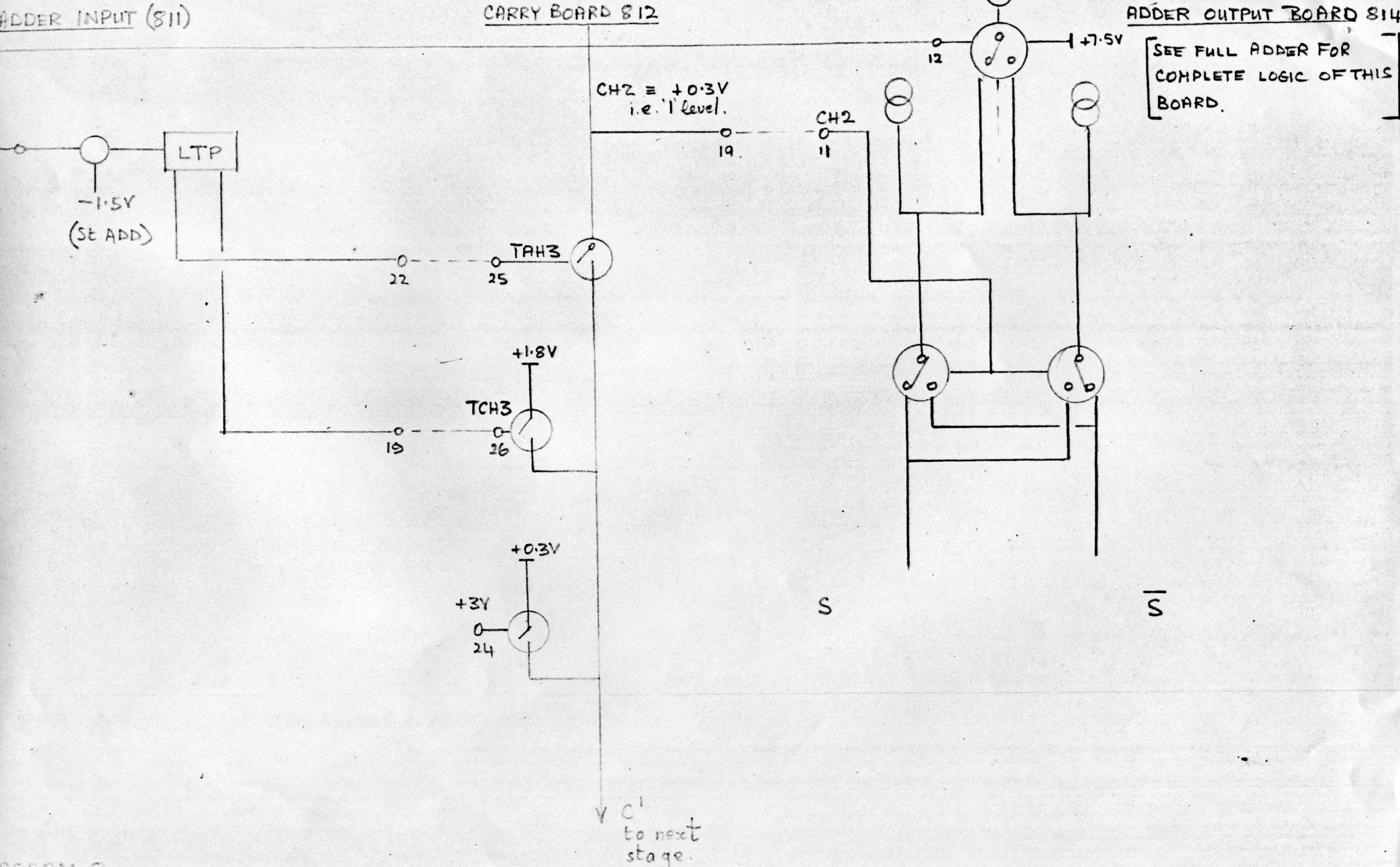



DIAGRAM 7

ROL HALF-ADDER




AGRAM 8

CONTROL HALF ADDER

| AK | $\overline{AK}$ | TAH | TCH | C | C' | S |
|---|---|---|---|---|---|---|
| 1 | 0 | 1 | 0 | 1 | 1 | 0 |

Original digit = 1
Answer (S) = 0
Carry = 1

} equivalent to adding 1 to the original digit

| AK | $\overline{AK}$ | TAH | TCH | C | C' | S |
|---|---|---|---|---|---|---|
| 0 | 1 | 0 | 1 | 1 | 0 | 1 |

Original digit = 0
Answer (S) =1
Carry = 0

} equivalent to adding 1 to the original digit

Diagram 9