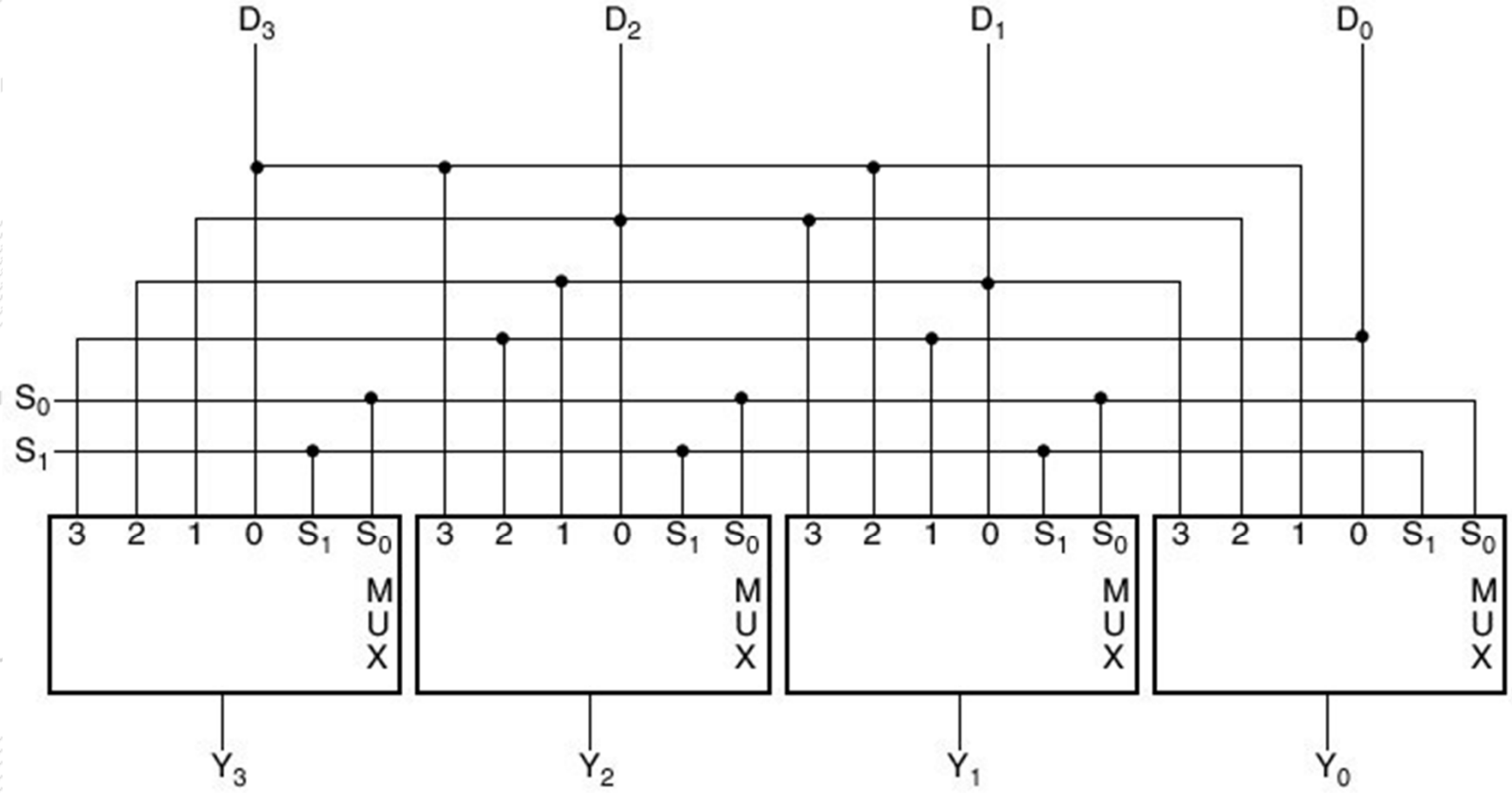
# CS2022 Shift Operations

- By controlling IR and IL with multiplexers it is straightforward to adapt this circuit to perform arithmetic shifts, constructive and destructive shifts, Rotates and rotate-then-carry operation

# CS2022 4-Bit Barrel Shifter



# CS2022 Multiple Shifts

- If multiple shifts are required we wire them into multiplexers that have an input for every bit on the bus to obtain a Barrel shifter (Previous slide).

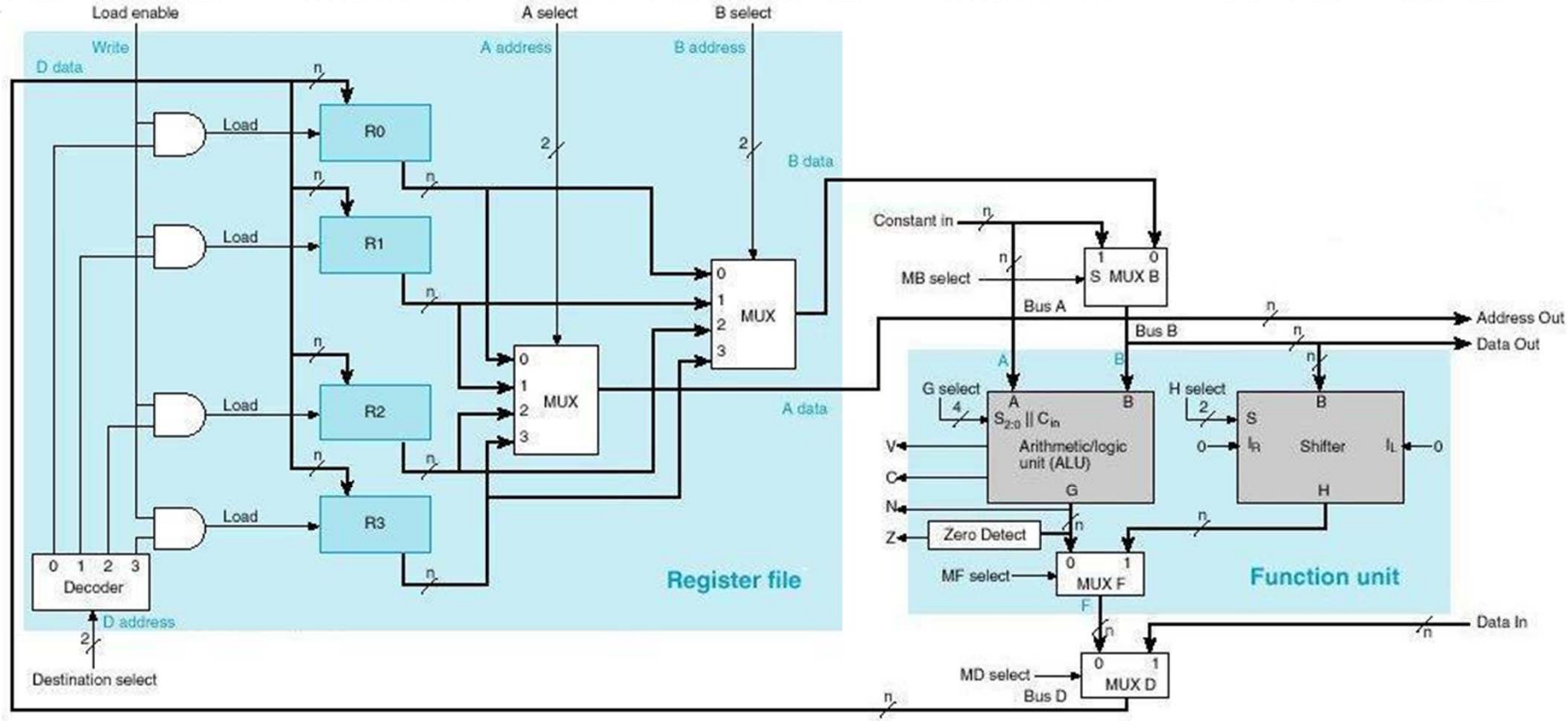
| $S_1$ $S_2$ | $Y_3$ $Y_2$ $Y_1$ $Y_0$ | Micro-ops |
|---|---|---|
| 0 0 | $D_3$ $D_2$ $D_1$ $D_0$ | No Rotate |
| 0 1 | $D_2$ $D_1$ $D_0$ $D_3$ | Rotate One |
| 1 0 | $D_1$ $D_0$ $D_3$ $D_2$ | Rotate Two |
| 1 1 | $D_0$ $D_3$ $D_2$ $D_1$ | Rotate Three |

# CS2022 Controlling a Datapath

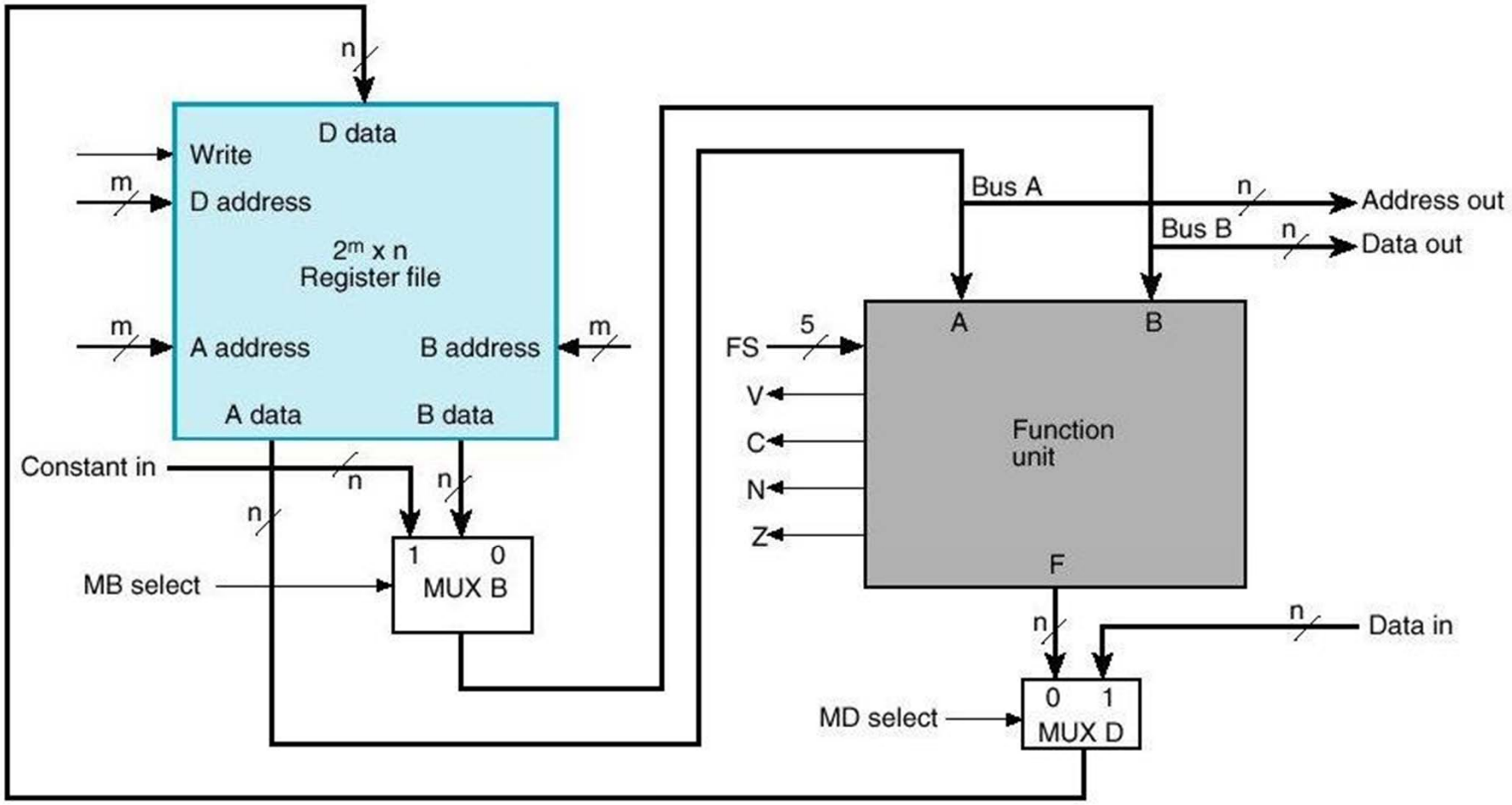
## The Control Word

- The figure on the next slide is an updated version of our introductory datapath (4th Lecture, Page 12) where the register file has been expanded to a more realistic eight n-bit registers.
- Consequently the destination decoder and A and B bus MUX require three-bit select input.
- The Function Unit still requires five bits to select ALU/Shift micro-ops.
- Three more bits are required to control:
  - Writing to the registers (RW)
  - MUX B (MB)
  - MUX D (MD)

# CS2022 4th Lecture - Page 12



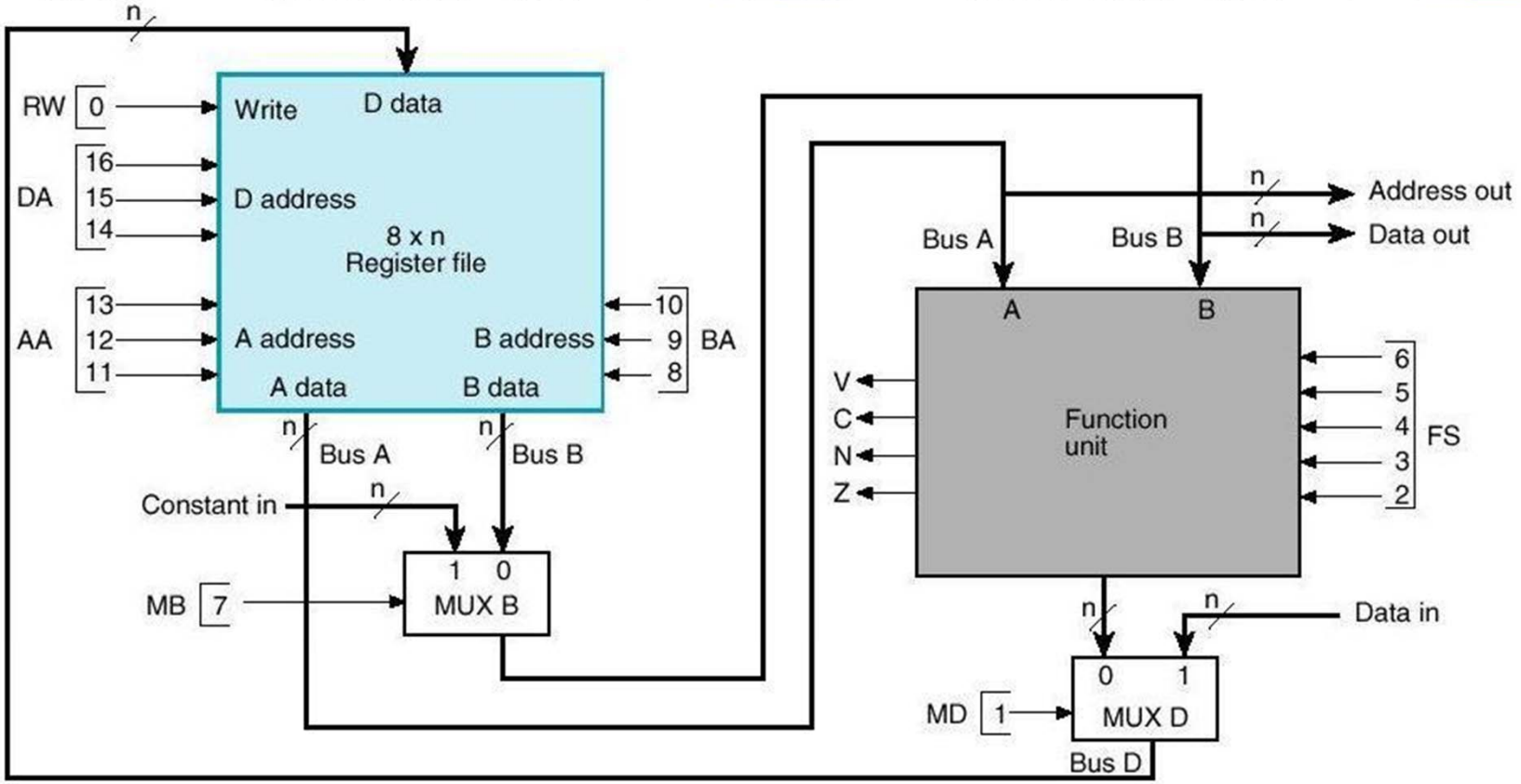
# CS2022 Updated Datapath

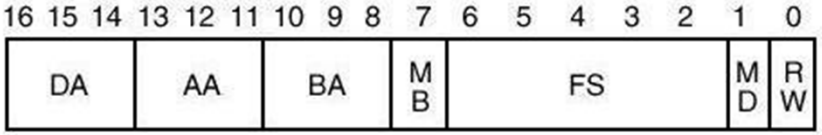


# CS2022 Control Word

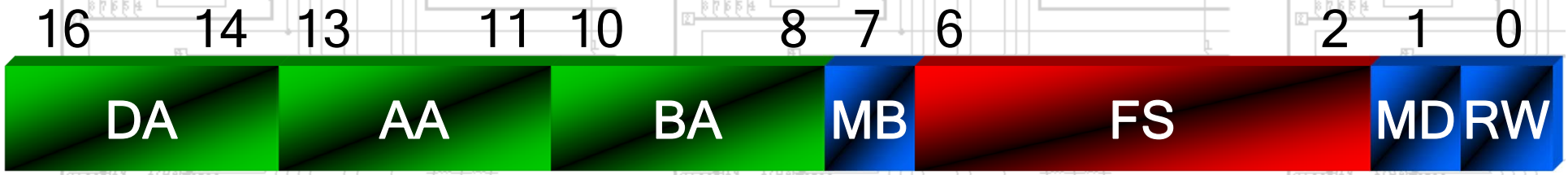
- The schematic on the next slide identifies all these control inputs and arranges them in a 17-bit vector called the Control Word.

# CS2022 Datapath and the Control Word



# The Control Word Specifies One Micro-ops

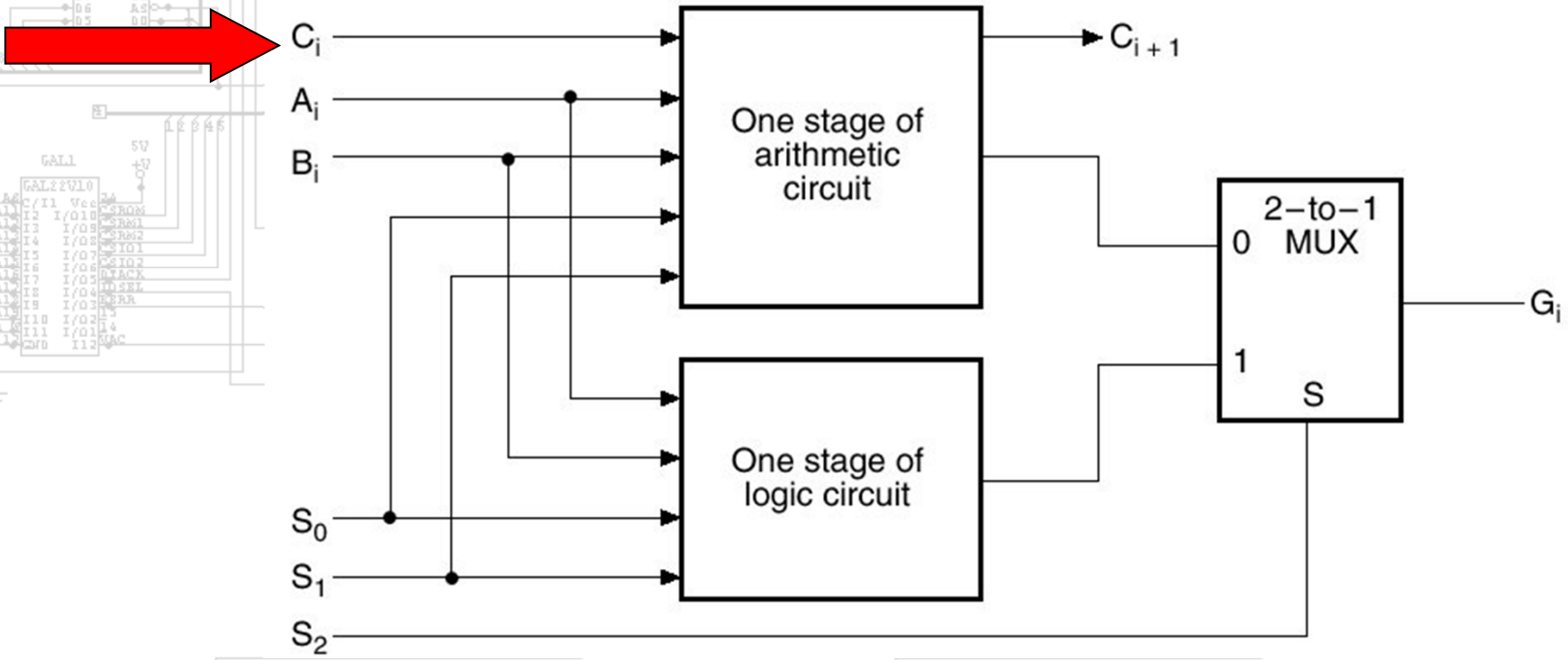



- Note that for the function select FS we need to make explicit the relationship between its value and the micro-ops.
  - See next slide for details.

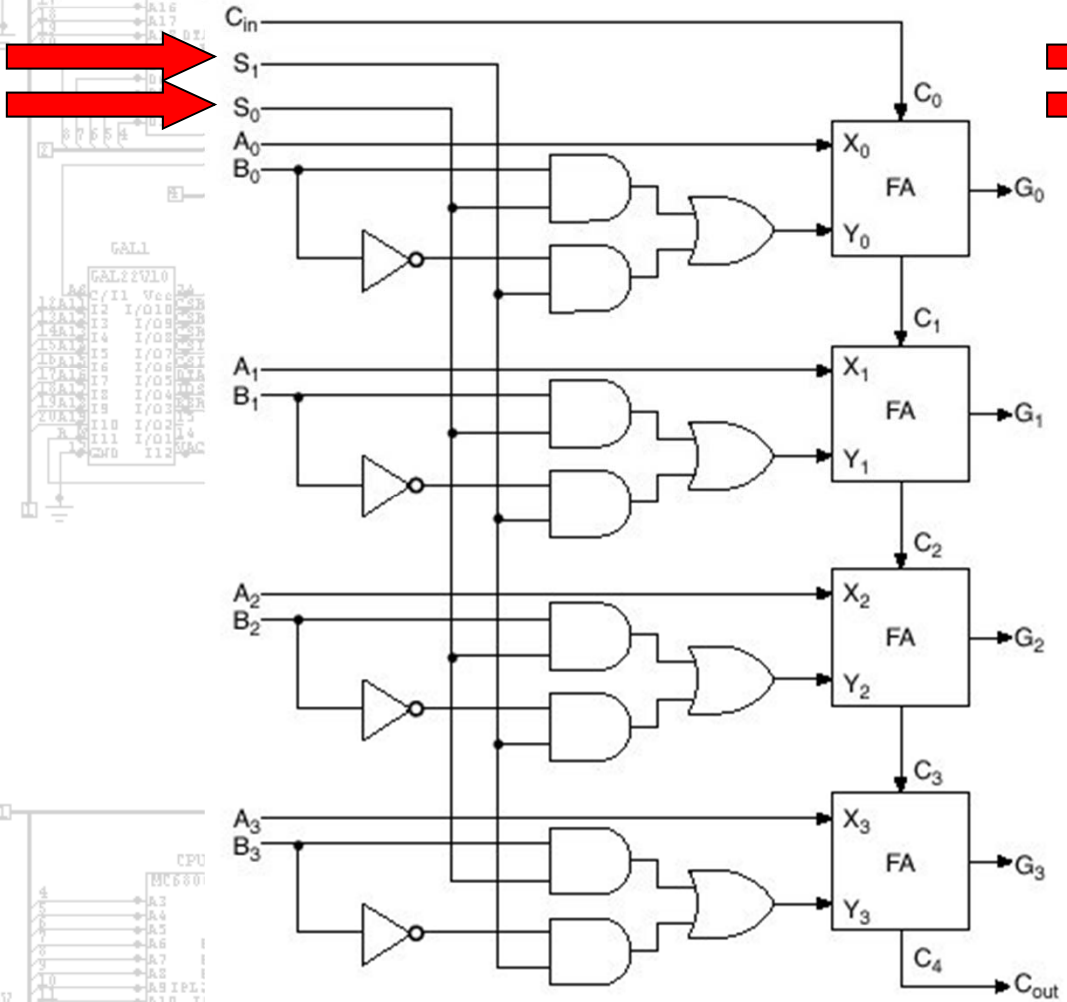
# G Select, H Select and MF Select determine the FS code

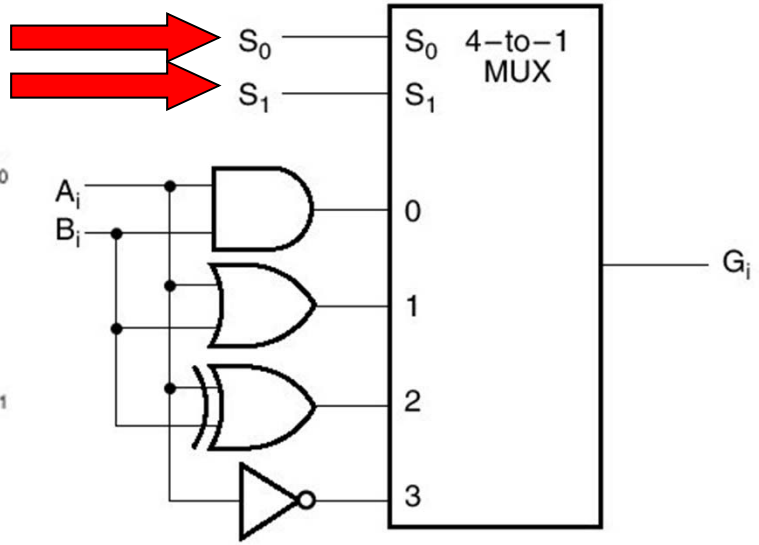
| FS | MF Select | G Select | H Select | Output | |
|---|---|---|---|---|---|
| 00000 | 0 | 0000 | XX | G = A | TRANSFER |
| 00001 | 0 | 0001 | XX | G = A + 1 | INCREMENT |
| 00010 | 0 | 0010 | XX | G = A + B | ADD |
| 00011 | 0 | 0011 | XX | G = A + B +1 | ADD WITH C |
| 00100 | 0 | 0100 | XX | G = A + $\overline{B}$ | A plus 1's C.B |
| 00101 | 0 | 0101 | XX | G = A + $\overline{B}$ +1 | SUBTRACT |
| 00110 | 0 | 0110 | XX | G = A - 1 | DECREMENT |
| 00111 | 0 | 0111 | XX | G = A | TRANSFER |
| 01000 | 0 | 1000 | XX | G = A $\wedge$ B | AND |
| 01010 | 0 | 1010 | XX | G = A $\vee$ B | OR |
| 01100 | 0 | 1100 | XX | G = $\overline{A} \oplus$ B | XOR |
| 01110 | 0 | 1110 | XX | G = $\overline{A}$ | NOT |
| 10000 | 1 | XXXX | 00 | G = B | TRANSFER |
| 10100 | 1 | XXXX | 01 | G = sr B | SHIFT RIGTH |
| 11000 | 1 | XXXX | 10 | G = sl B | SHIFT LEFT |

# CS2022 FS[2]= $C_{in}$

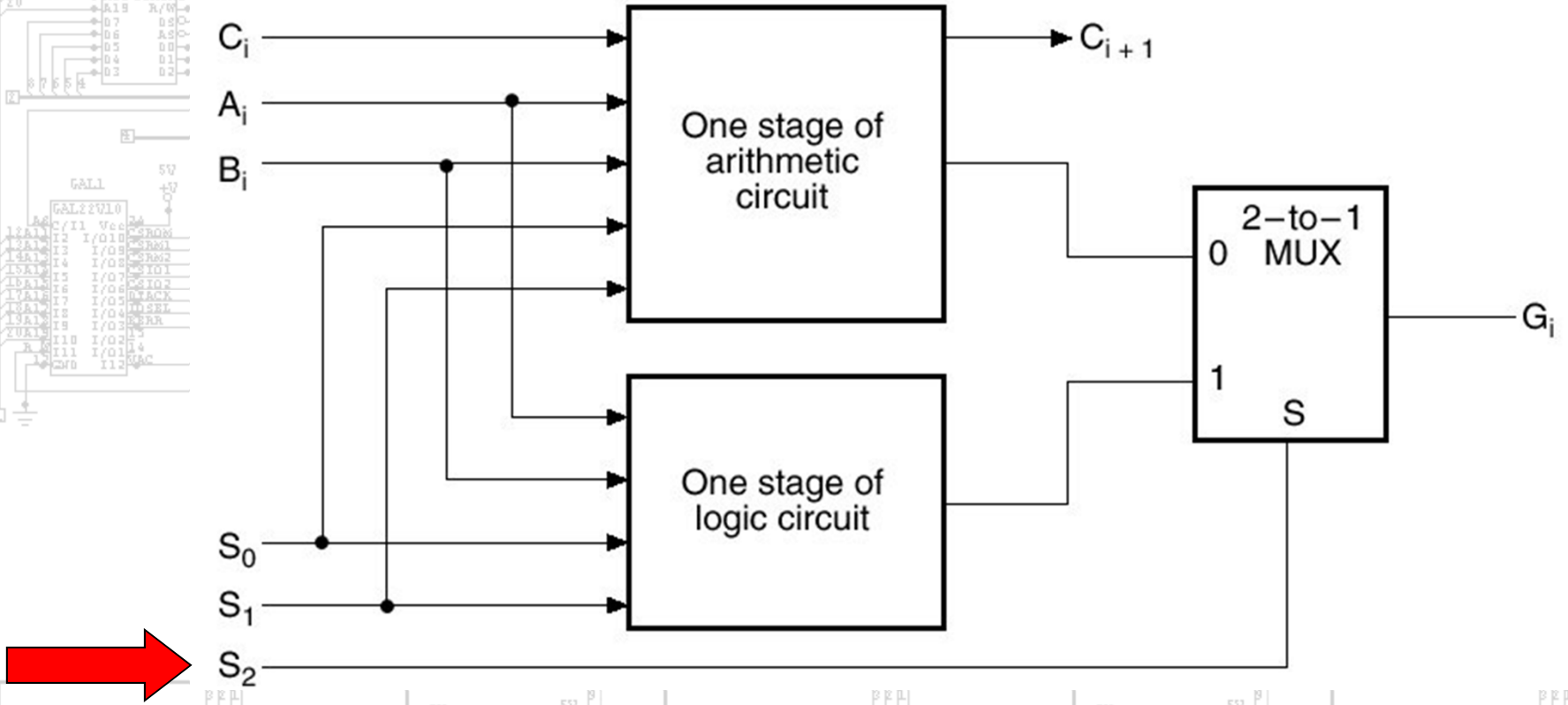


# CS2022 $FS[3 \wedge 4] = S_0 S_1$



# CS2022 FS[5]=$S_2$



# CS2022 FS[6]=MF select