CSCI 210: Computer Architecture
Lecture 9: Logical Operations

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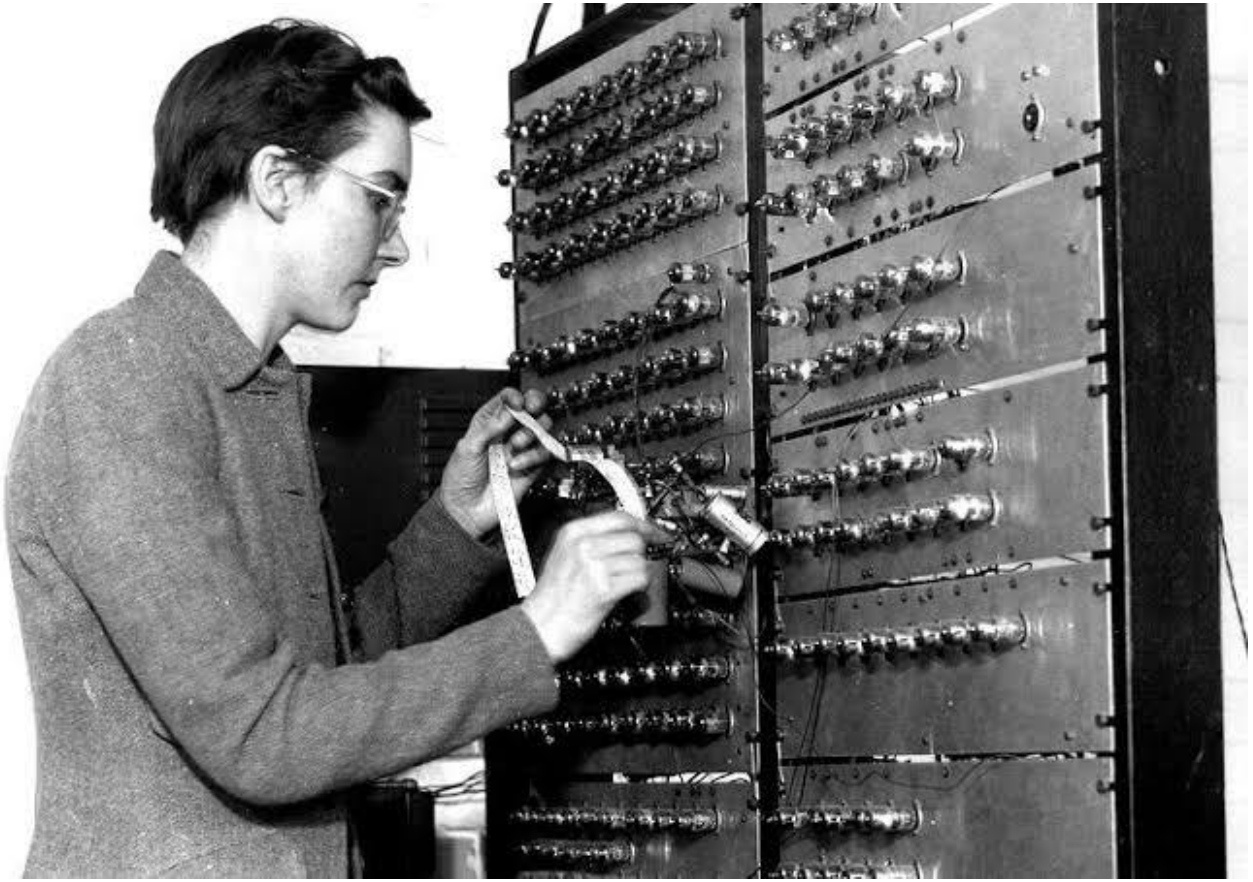


- Applied mathematician and computer scientist
- Wrote the first assembly language and assembler in 1947
- Collaborated with Andrew Booth to develop three early computers: the ARC (Automatic Relay Calculator), SEC (Simple Electronic Computer), and APE(X)C
- Later worked with neural nets

Logical Operations

- Instructions for bitwise manipulation

Operation	C	Java	MIPS
Shift left	<<	<<	`sll`
Shift right	>>	>>>	`srl`
Bitwise AND	&	&	`and, andi`
Bitwise OR	|	|	`or, ori`
Bitwise NOT	~	~	`nor`

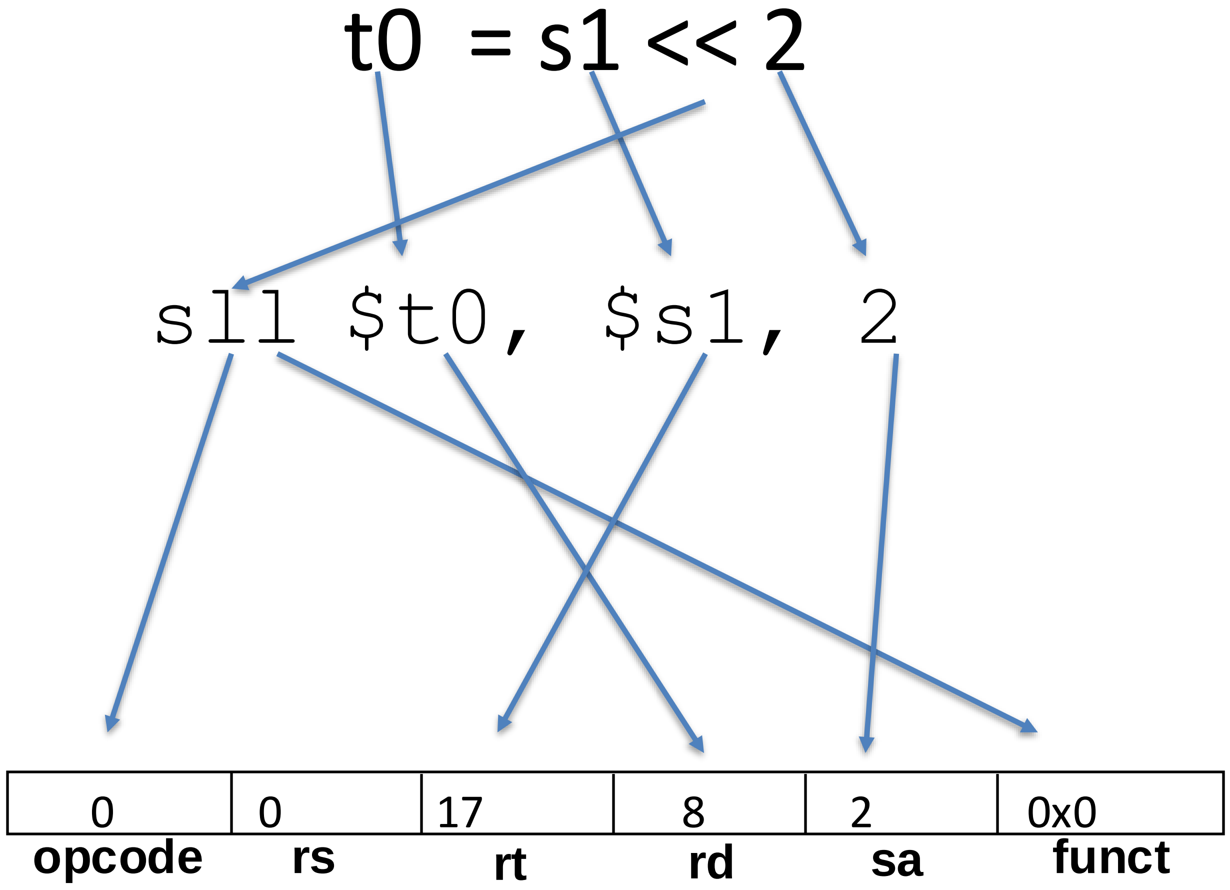
- Useful for extracting and inserting groups of bits in a word

Shift Operations

op	rs	rt	rd	shamt	funct
6 bits	5 bits	5 bits	5 bits	5 bits	6 bits

- shamt: how many positions to shift
- Shift left logical
  - Shift left and fill with 0 bits
  - sll by n bits multiplies by 2^n
- Shift right logical
  - Shift right and fill with 0 bits
  - srl by n bits divides by 2^n (unsigned only)

MIPS shift instructions



Shift left logical

- 0110 1001 << 2 in 8 bits
  - Most significant 2 bits are dropped
  - 2 0s are added to become the least significant bits
  - Result: ~~01~~ 1010 0100 => 1010 0100

Shift right logical

- 1010 1001 >>> 3 in 8 bits
  - Least significant 3 bits are dropped
  - 3 0s are added to become the most significant bits
  - Result: 0001 0101 ~~001~~ => 0001 0101

Shift right arithmetic

- sra rd, rt, shamt
  - Shift right and copy the sign bit
- 1010 1001 >> 3 in 8 bits
  - Least significant 3 bits are dropped
  - 3 1s are added because the MSB is 1 to become the most significant bits
  - Result: 1111 0101 ~~001~~ => 1111 0101

A new op HEXSHIFTRIGHT shifts hex numbers right by a digit. HEXSHIFTRIGHT *i* times is equivalent to

A. Dividing by *i*

B. Dividing by 2^i

C. Dividing by 16^i

D. Multiplying by 16^i

Remember Boolean Operations?

- and, or, not . . .
- Now we’ll apply them to bits!
- Just think of 1 as True, and 0 as False

And Truth Table

	0	***1***
0	0	0
1	0	1

AND Operations

- Useful to mask bits in a word
  - Select some bits, clear others to 0

```
and $t0, $t1, $t2
```

$t2	0000 0000 0000 0000 0000 1101 1100 0000
$t1	0000 0000 0000 0000 0011 1100 0000 0000
$t0	0000 0000 0000 0000 0000 1100 0000 0000

AND identities (for a single bit)

- x & 0 =
- x & 1 =

01101001 & 11000111

A. 00010000

B. 01000001

C. 10101110

D. 11101111

If we want to zero out bits* 3 – 0 in a byte we should AND with

A. 00000000

B. 00001111

C. 11110000

D. 11111111

*MSB (bit 7) is on the left,
LSB (bit 0) is on the right

Or Truth Table

	0	***1***
0	0	1
1	1	1

OR Operations

- Useful to set bits in a word
  - Set some bits to 1, leave others unchanged

```
or $t0, $t1, $t2
```

$t2	0000 0000 0000 0000 0000 1101 1100 0000
$t1	0000 0000 0000 0000 0011 1100 0000 0000
$t0	0000 0000 0000 0000 0011 1101 1100 0000

OR Identities (for a single bit)

- x | 0 =
- x | 1 =

01101001 | 11000111

A. 00010000

B. 01000001

C. 10101110

D. 11101111

Nor Truth Table

	0	***1***
0	1	0
1	0	0

NOR Operations

- MIPS has NOR 3-operand instruction
  - a NOR b = NOT (a OR b)

```
nor $t0, $t1, $t2
```

$t2	0000 0000 0000 0000 0000 1101 1100 0000
$t1	0000 0000 0000 0000 0011 1100 0000 0000
$t0	1111 1111 1111 1111 1100 0010 0011 1111

01101001 NOR 11000111

A. 00010000

B. 01000001

C. 10101110

D. 11101111

NOT operations

- Inverts all the bits in a word
  - Change 0 to 1, and 1 to 0

MIPs does not need a NOT operation because we can use ____ for NOT $t1, $t2

A. `nor $t1, $t2, $zero`

B. `nor $t1, $t2, $t3`, where all bits in `$t3` are set to 1

C. `nori $t1, $t2, 0b1111111_111111111`, where nori is Nor Immediate

D. It does require a NOT operation

E. None of the above are correct

XOR Truth Table

	0	***1***
0	0	1
1	1	0

XOR Operations

- Exclusive OR (written x ⊕ y or x ^ y)
  - Set bits to one only if they are not the same

```
xor $t0, $t1, $t2
```

$t2	0000 0000 0000 0000 0000 1101 1100 0000
$t1	0000 0000 0000 0000 0011 1100 0000 0000
$t0	0000 0000 0000 0000 0011 0001 1100 0000

01101001 XOR 11000111

A. 00010000

B. 01000001

C. 10101110

D. 11101111

XOR Identities (for a single bit)

- x XOR 0 =
- x XOR 1 =

10 & 7

A. 0

B. 2

C. 7

D. 10

E. None of the above

Set bit 4 in byte x to 1, leaving the rest of the bits unchanged

A. x = x AND 00010000

B. x = x AND 11101111

C. x = x OR 00010000

D. x = x NOR 11101111

Invert bits 2–0 of x

A. x = x AND 00000111

B. x = x OR 00000111

C. x = x NOR 00000111

D. x = x XOR 00000111

Find the ones’ complement of x (in 8 bits)

A. x XOR 00000000

B. x XOR 11111111

C. x XOR 11111110

D. x OR 11111111

Reading

- Next lecture: Branching instructions