CS64 Week 7 Lecture 1

Kyle Dewey

Overview

- Multiplexers

Multiplexers

Motivation

- At this point, you've seen a lot of straightline circuits
- However, this doesn't quite match up with respect to what a processor does. Why?

Motivation

- At this point, you've seen a lot of straightline circuits
- However, this doesn't quite match up with respect to what a processor does. Why?
  - We don't always do the same thing - it depends on the instruction
  - What do we need here?

Motivation

- At this point, you've seen a lot of straightline circuits
- However, this doesn't quite match up with respect to what a processor does. Why?
  - We don't always do the same thing - it depends on the instruction
  - What do we need here?
    - Some form of a conditional

Conditional

- Assume `selector`, `A`, `B`, and `R` all hold a single bit
- How can we implement this using what we have seen so far? (Hint: what does the truth table look like?)

```
R = (selector) ? A : B
```

R = (selector) ? A : B

S	A	B	R
0	0	0	0
0	0	1	1
0	1	0	0
0	1	1	1
1	0	0	0
1	0	1	0
1	1	0	1
1	1	1	1

`R = (selector) ? A : B`

S	A	B	R
0	0	0	0
0	0	1	1
0	1	0	0
0	1	1	1
1	0	0	0
1	0	1	0
1	1	0	1
1	1	1	1

Unreduced sum-of-products:

`R = !S!AB + !SAB + SA!B + SAB`

R = (selector) ? A : B

S	A	B	R
0	0	0	0
0	0	1	1
0	1	0	0
0	1	1	1
1	0	0	0
1	0	1	0
1	1	0	1
1	1	1	1

Unreduced sum-of-products:

R = !S!AB + !SAB + SA!B + SAB

Reduced sum-of-products:

R = !SB + SA

Slight Modification

Original

```
R = (selector) ? A : B
```

Modified

```
R = (selector) ? doThis() : doThat()
```

Slight Modification

Original

```
R = (selector) ? A : B
```

Modified

```
R = (selector) ? doThis() : doThat()
```

Intended semantics: either `doThis()` or `doThat()` is executed. Our formula from before doesn't satisfy this property:

```
R = !S*doThat() + S*doThis()
```

Slight Modification

Original

```
R = (selector) ? A : B
```

Modified

```
R = (selector) ? doThis() : doThat()
```

- Fixing this is hard, but possible
- Involves circuitry we'll learn later
- Oddly enough, this isn't as big of a problem as it seems, and it's ironically *faster* than doing just one or the other. Why?

Slight Modification

Original

```
R = (selector) ? A : B
```

Modified

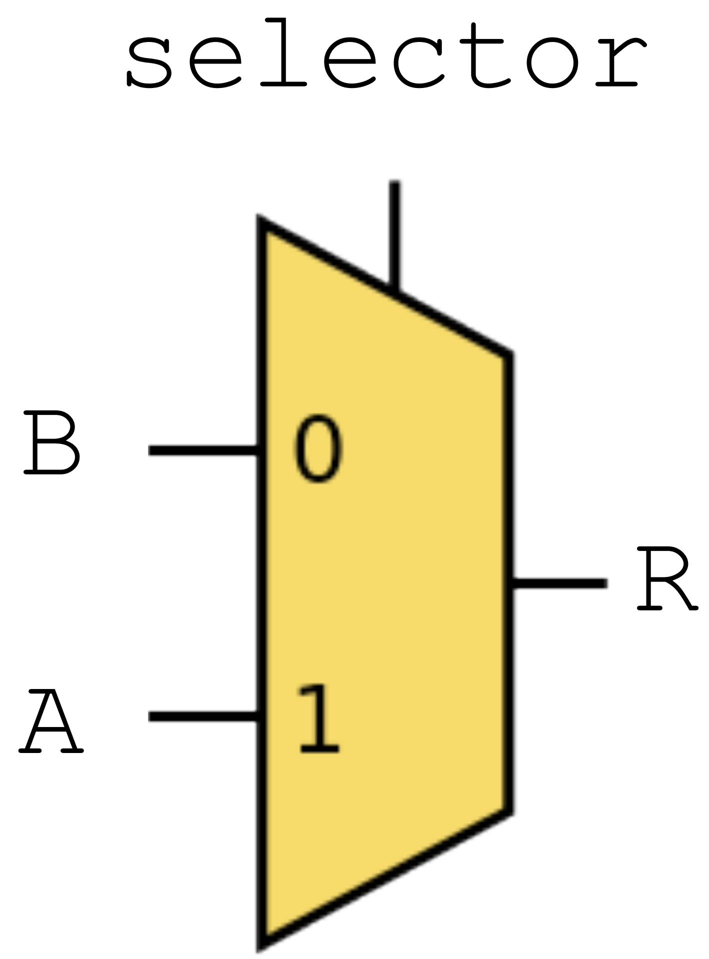
```
R = (selector) ? doThis() : doThat()
```

- Oddly enough, this isn't as big of a problem as it seems, and it's ironically *faster* than doing just one or the other. Why? - branches executed in parallel at the hardware level. Faster because extra circuitry is extra.

Multiplexer

- Component that does exactly this:

```
R = (selector) ? A : B
```



Question

- Recall the arithmetic logic unit (ALU), which is used to add, subtract, shift, perform bitwise operations, etc.
- How might a multiplexer be useful for an ALU?

				Opcode / Function
Add Unsigned	addu	R	R[rd] = R[rs] + R[rt]	$0 / 21_{hex}$
And	and	R	R[rd] = R[rs] & R[rt]	$0 / 24_{hex}$

Question

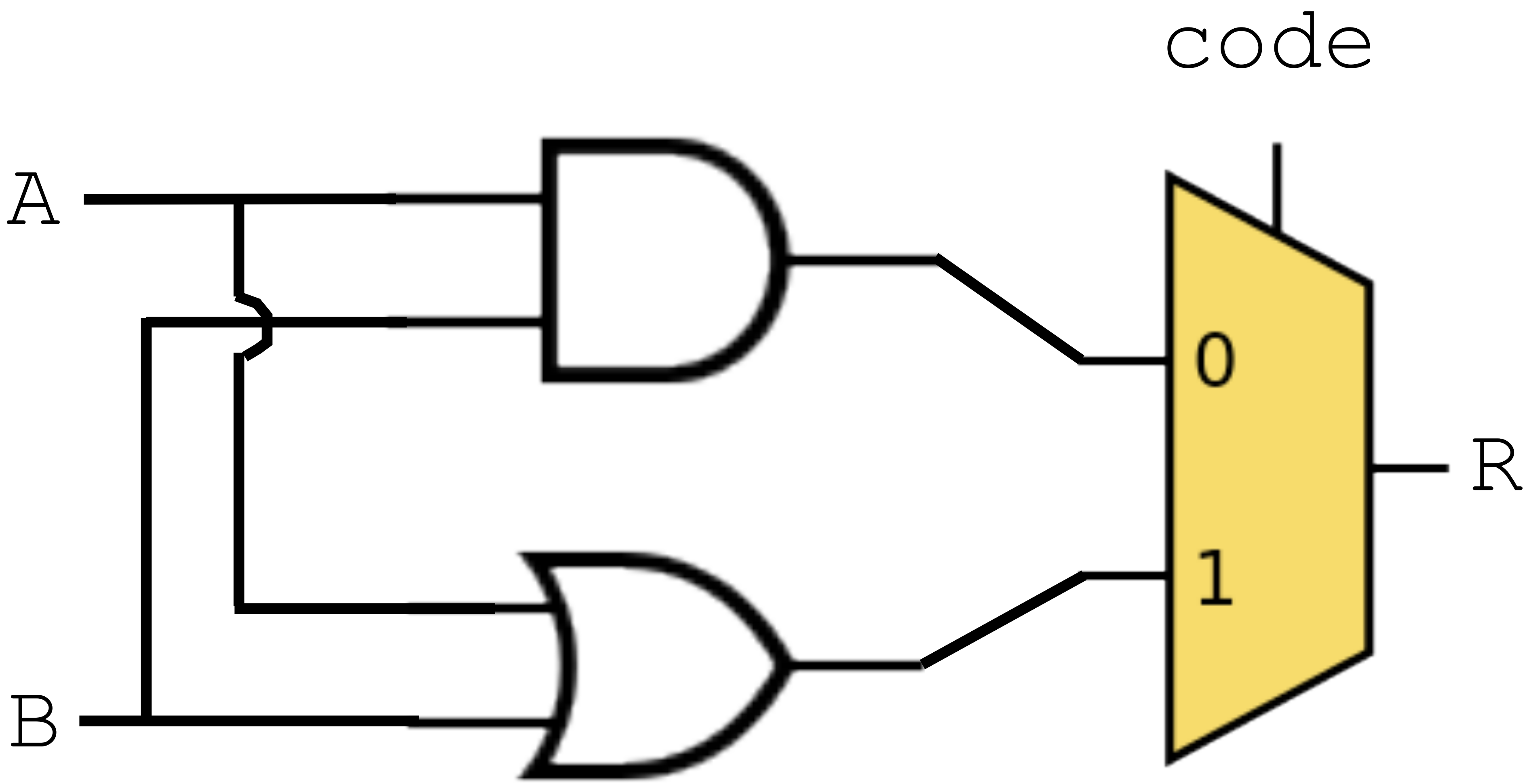
- Recall the arithmetic logic unit (ALU), which is used to add, subtract, shift, perform bitwise operations, etc.
- How might a multiplexer be useful for an ALU? - Do all operations at once in parallel, and then use a multiplexer to select the one you want

				Opcode / Function
Add Unsigned	addu	R	R[rd] = R[rs] + R[rt]	$0 / 21_{hex}$
And	and	R	R[rd] = R[rs] & R[rt]	$0 / 24_{hex}$

Example

- Let's design a one-bit ALU that can do bitwise AND and bitwise OR
- It has three inputs: `A`, `B`, and `S`, along with one output `R`
- S is a code provided indicating which operation to perform; `0` for AND and `1` for OR

Example

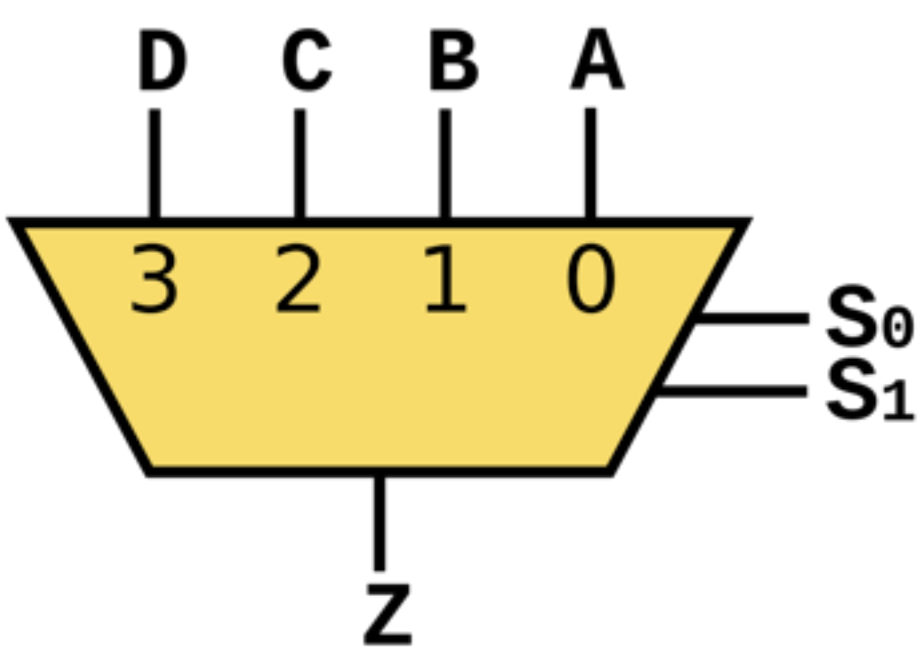


Bigger Multiplexers

- Can have a multiplexer with more than two inputs
- Need multiple select lines in this case
- Question: how many select lines do we need for a 4 input multiplexer?

Bigger Multiplexers

- Can have a multiplexer with more than two inputs
- Need multiple select lines in this case
- Question: how many select lines do we need for a 4 input multiplexer? - 2. Values of different lines essentially encode different binary integers.



Bigger Multiplexers

- We can build up bigger multiplexers from 2-input multiplexers. How?