CHAPTER IX

REGISTER BLOCKS
COUNTERS, SHIFT, AND ROTATE REGISTERS

READ PAGES 249-275 FROM MANO AND KIME

REGISTER BLOCKS

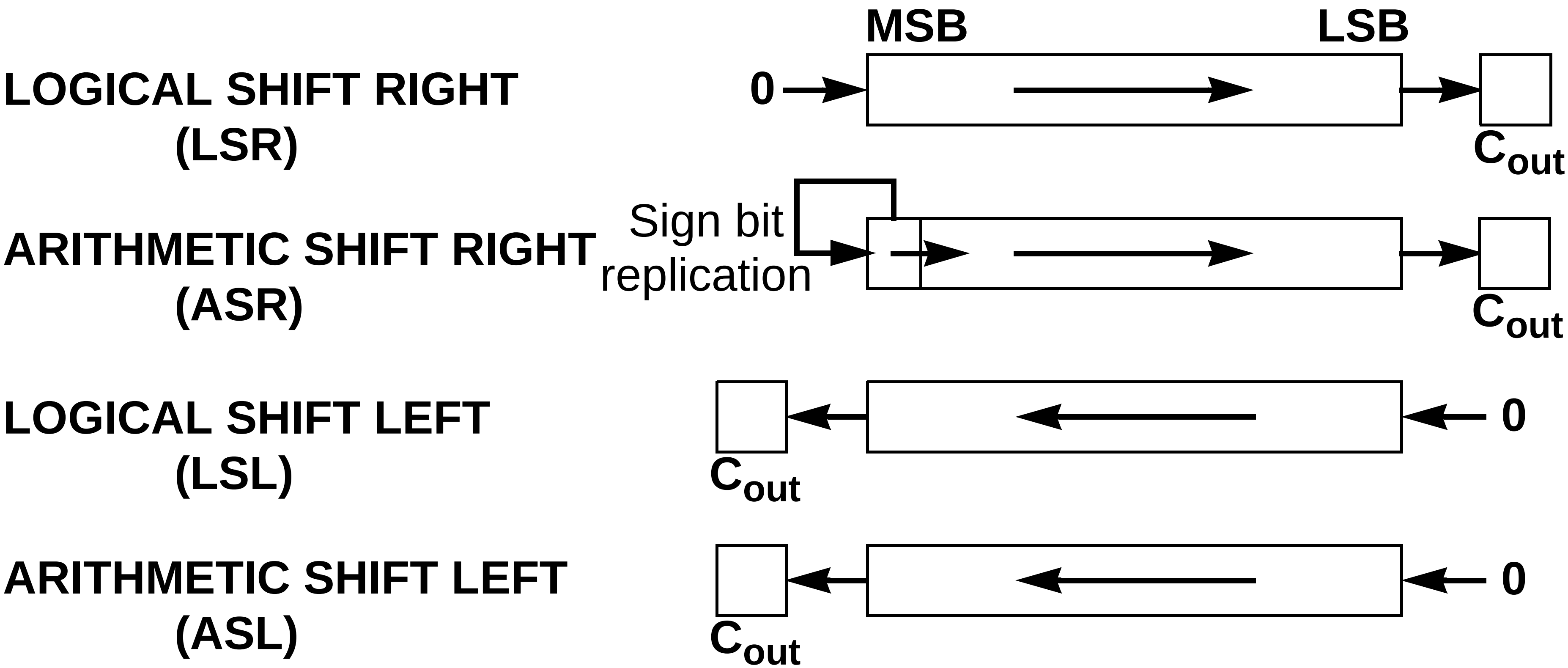
INTRODUCTION

- Like combinational building blocks, we can also develop some simple building blocks using registers. These include:
  - Shift registers
  - Rotate registers
  - Counters
- Implementations of these components can use state machines, but, it is often easier to think of them without the complication of a state machine.

SHIFT REGISTERS

INTRODUCTION

- Logical shift registers take the bits stored and move them up a significant bit or down a significant bit.

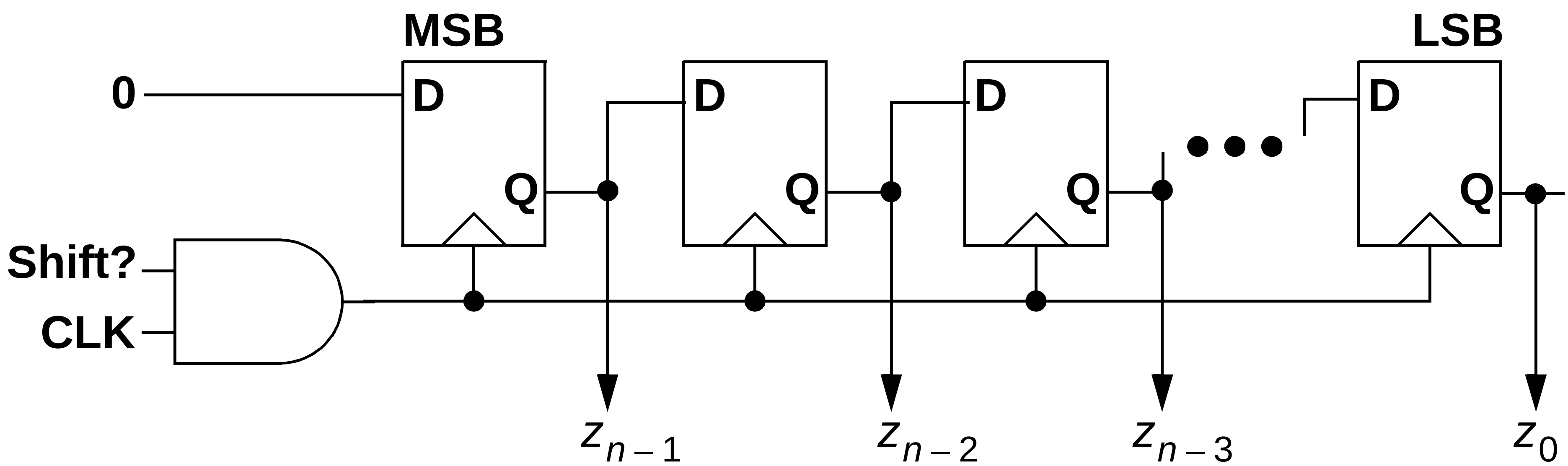


- Notice that logical and arithmetic shift lefts are the same.

SHIFT REGISTERS

LSR SAMPLE

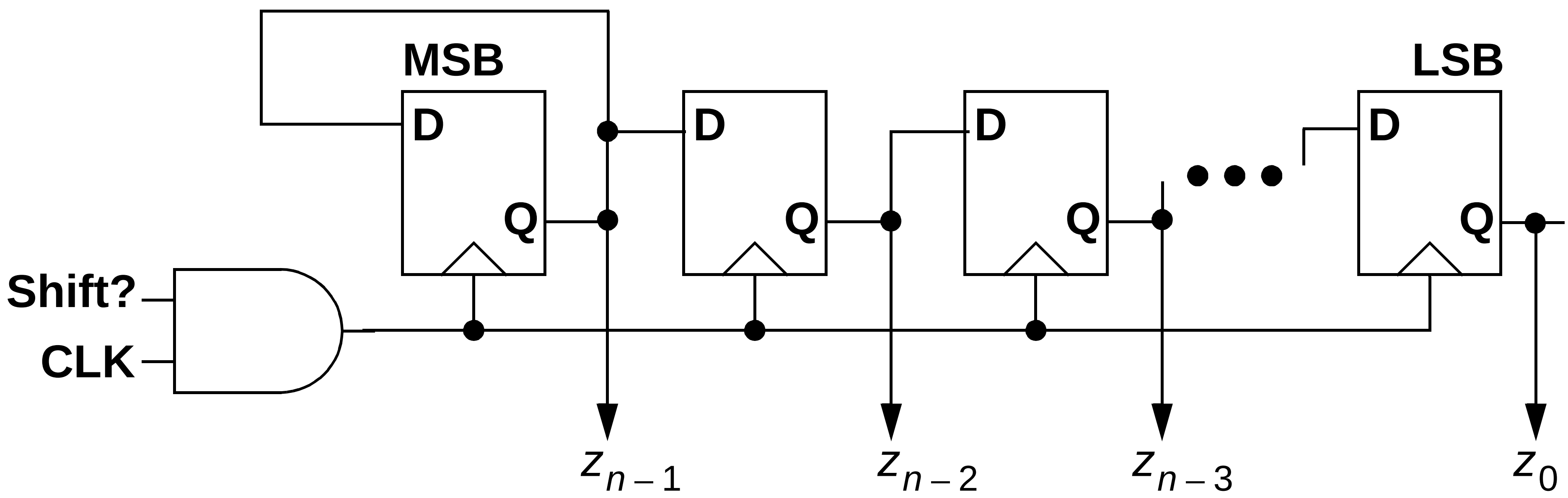
- A simple implementation of a logical right shift register might look like the following.



SHIFT REGISTERS

ASR SAMPLE

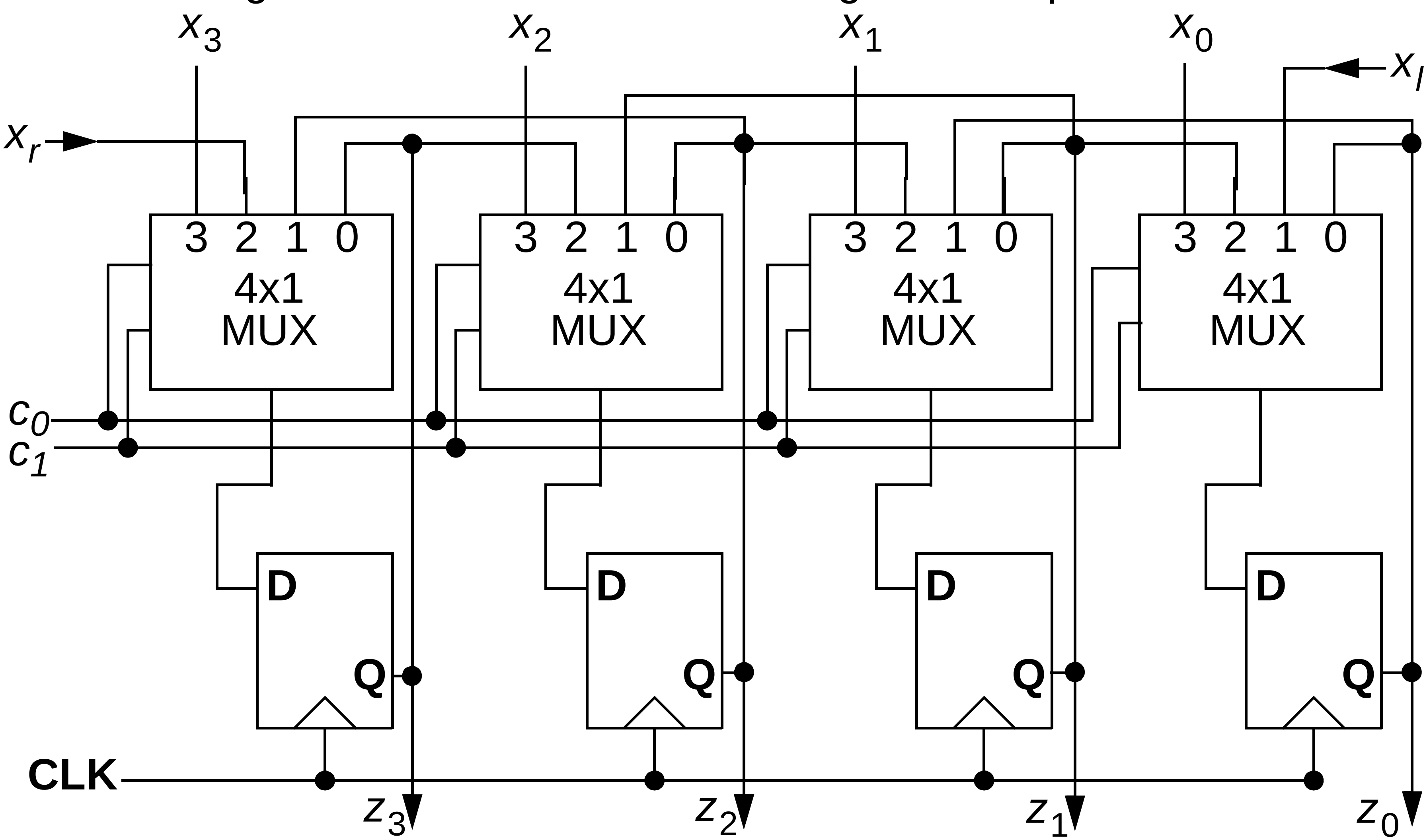
- An arithmetic right shift register might look like the following.



SHIFT REGISTERS

4-BIT BIDIRECTIONAL

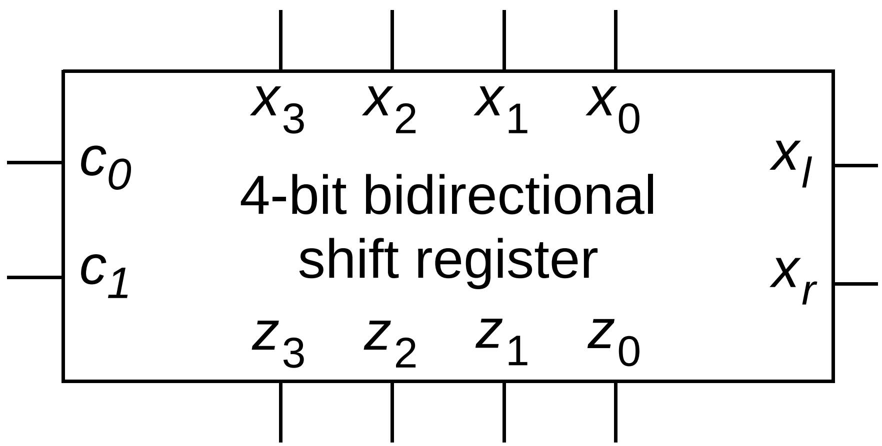
- The following is a 4-bit bidirectional shift register with parallel load.



SHIFT REGISTERS

CASCADING (1)

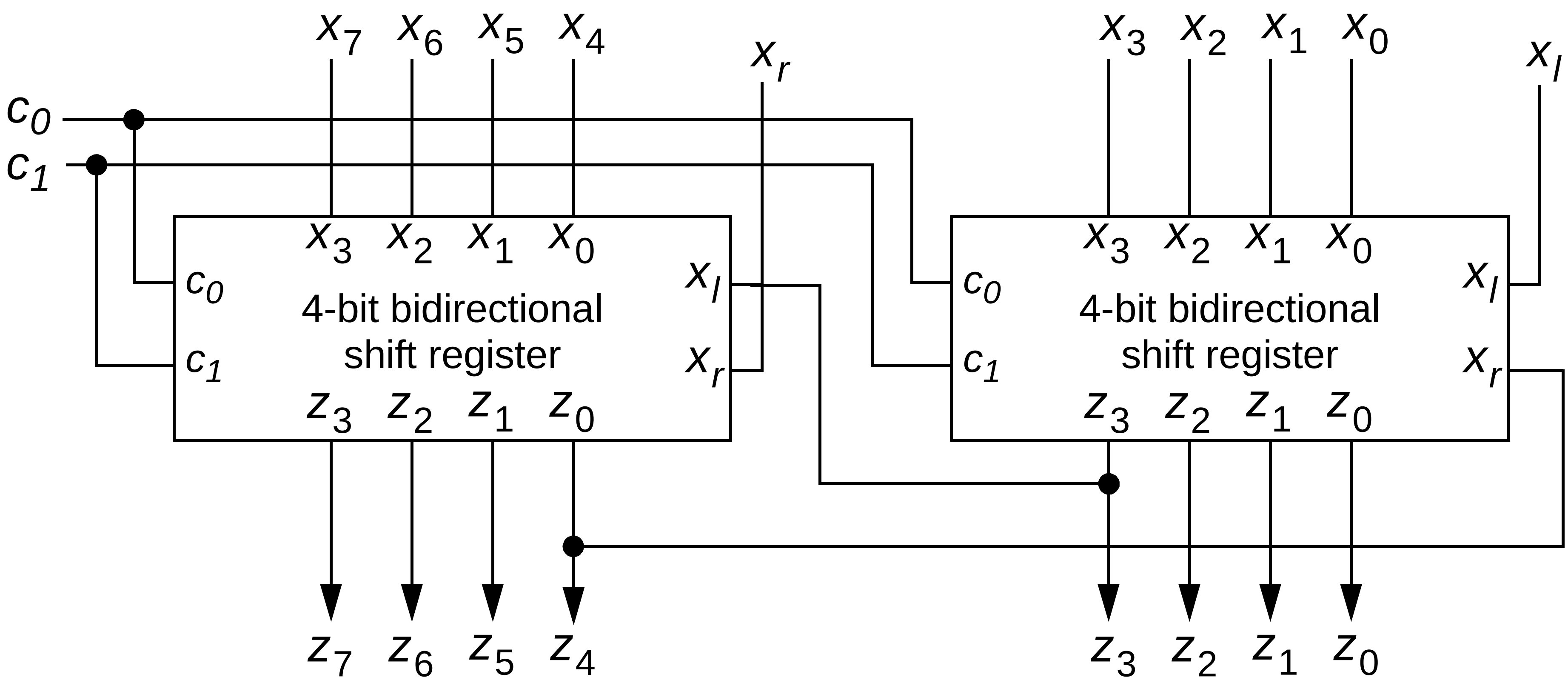
- Cascading of shift registers can also be done if the discarded bit is used to shift into another shift register module.
- For instance, the 4-bit bidirectional shift register previously presented can be easily cascaded using the
  - x_r (right shift data input) and
  - x_l (left shift data input)



SHIFT REGISTERS

CASCADING (2)

- For example, an 8-bit bidirectional shift register with parallel load can be formed as follows.



ROTATE REGISTERS

INTRODUCTION

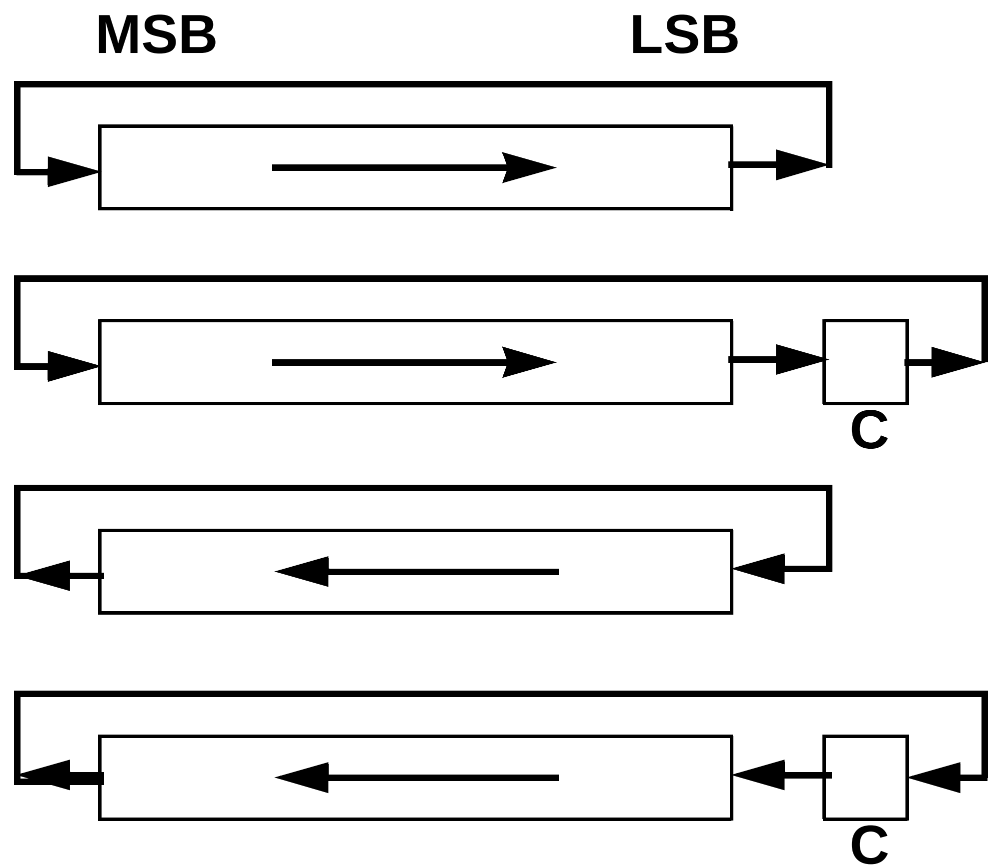
- A rotate register is the same as a logical shift register except that the discarded bit is fed back into the empty space from the shift.

ROTATE RIGHT

ROTATE RIGHT WITH CARRY

ROTATE LEFT

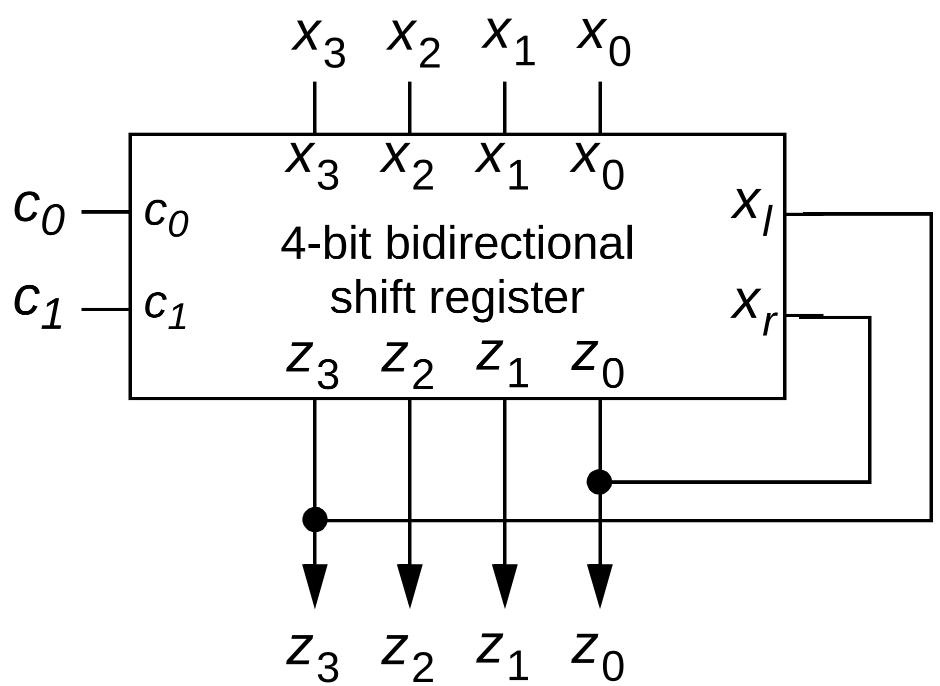
ROTATE LEFT WITH CARRY



ROTATE REGISTERS

USING SHIFT REGISTERS

- Rotate registers can actually be implemented using shift registers that have serial data inputs (such as the 4-bit bidirectional shift register discussed).
- For example, a 4-bit rotate register can be formed as follows.



COUNTERS

INTRODUCTION

- A counter is a register that on each clock pulse counts up or down, usually in binary.
- Types of counters
  - ripple counters
  - synchronous counters
  - binary counters
  - BCD counters
  - Gray-code counters
  - Ring counters (a 1 moves in a ring from one flip-flop to the next)
  - up/down counters (ability to increment or decrement)
  - counters with a parallel load (load in starting value with parallel input)

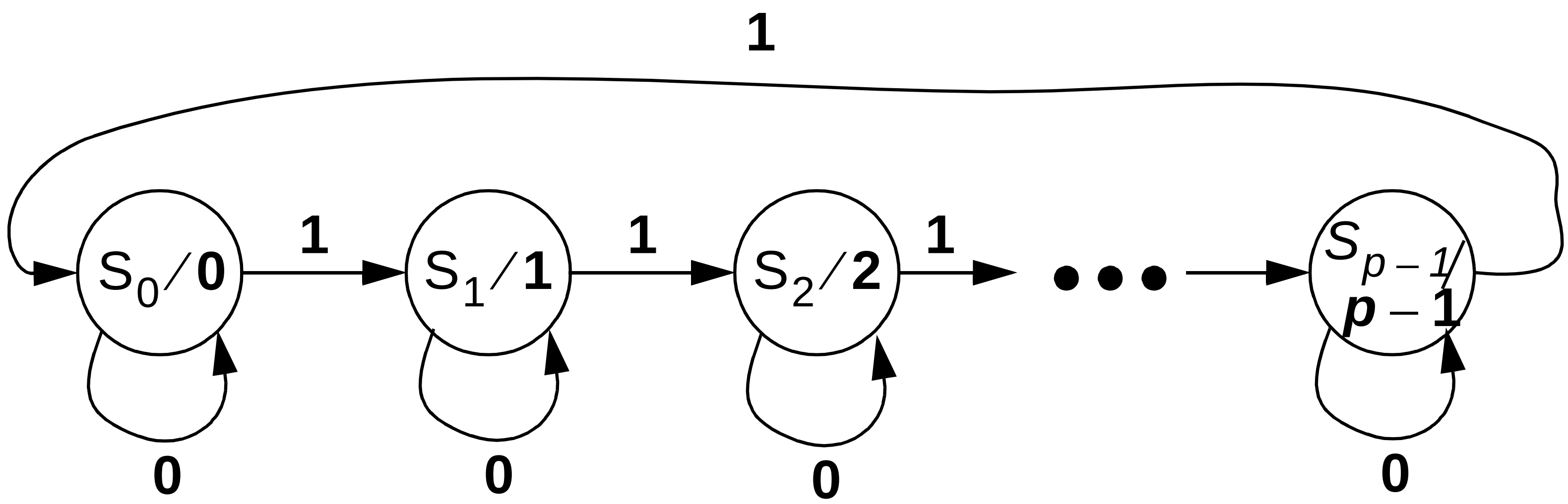
COUNTERS

MODULO-*P* COUNTERS

- A modulo-*p* counter is defined by the following equation.

$$S(t+1) = (S(t)+x)\ mod\ p$$

- The state diagram for the modulo-*p* counter is as follows.



COUNTERS

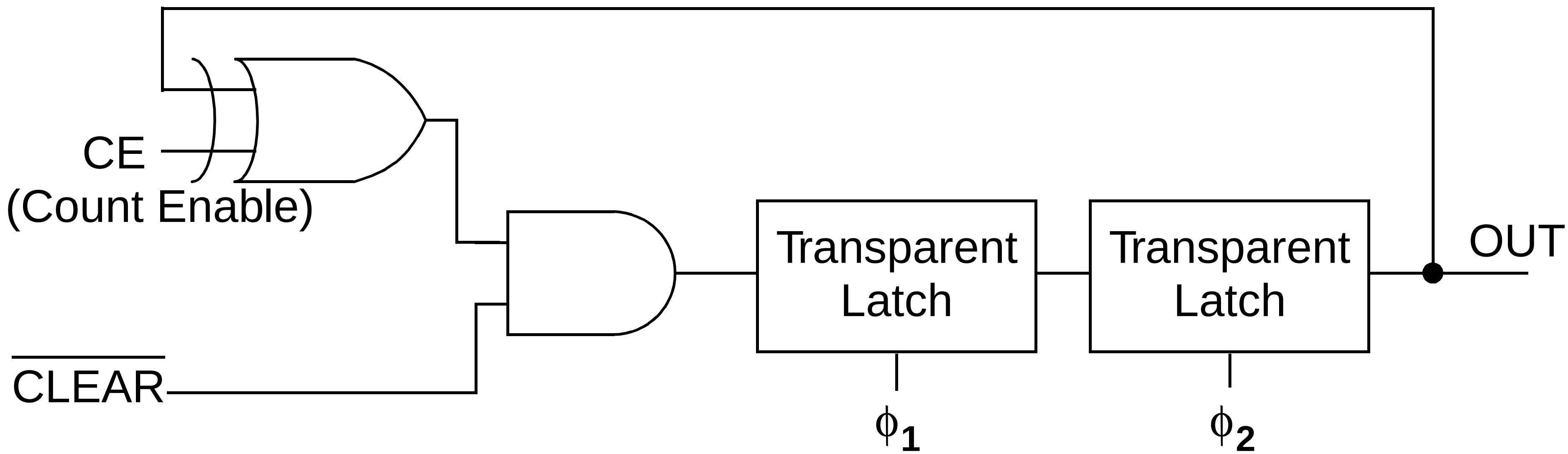
RIPPLE AND SYNCHRONOUS

- An *n*-bit binary counter consists of *n* flip-flops and can count in binary from 0 through $2^n - 1$.
  - This can be formed with a modulo-*p* counter where $p = 2^n$.
- Two main categories exist for counters:
  - Ripple counters
    - One flip-flop transition serves to trigger other flip-flops.
    - The clock pulse is usually only sent to the first flip-flop.
    - This requires a memory cell that can complement its value.
    - The JK flip-flip would be one approach (we have not studied this!)
  - Synchronous counters
    - Change of state is determined from the present state.
    - Clock pulse sent to all flip-flops.

COUNTERS

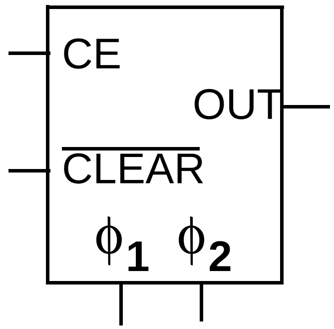
TOGGLE CELL

- A toggle cell will be useful for implementing counters.



Present Latch Value	CE	$\overline{\text{CLEAR}}$	Next Latch Value	OUT
X	**X**	**0**	**0**	**?**
0	**0**	**1**	**0**	**0**
1	**0**	**1**	**1**	**1**
0	**1**	**1**	**1**	**0**
1	**1**	**1**	**0**	**1**

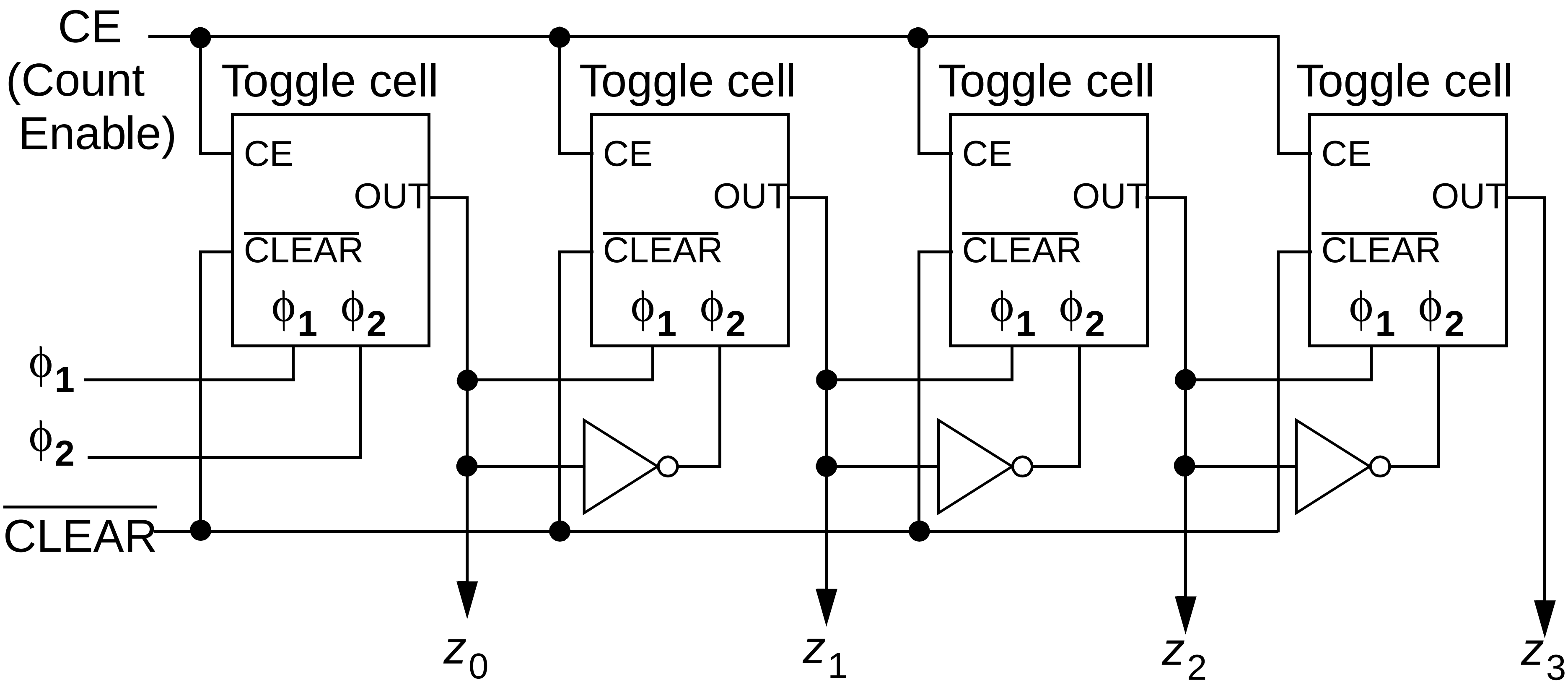
Toggle cell



COUNTERS

RIPPLE COUNTER

- The toggle cell can be used as follows to form a ripple counter.

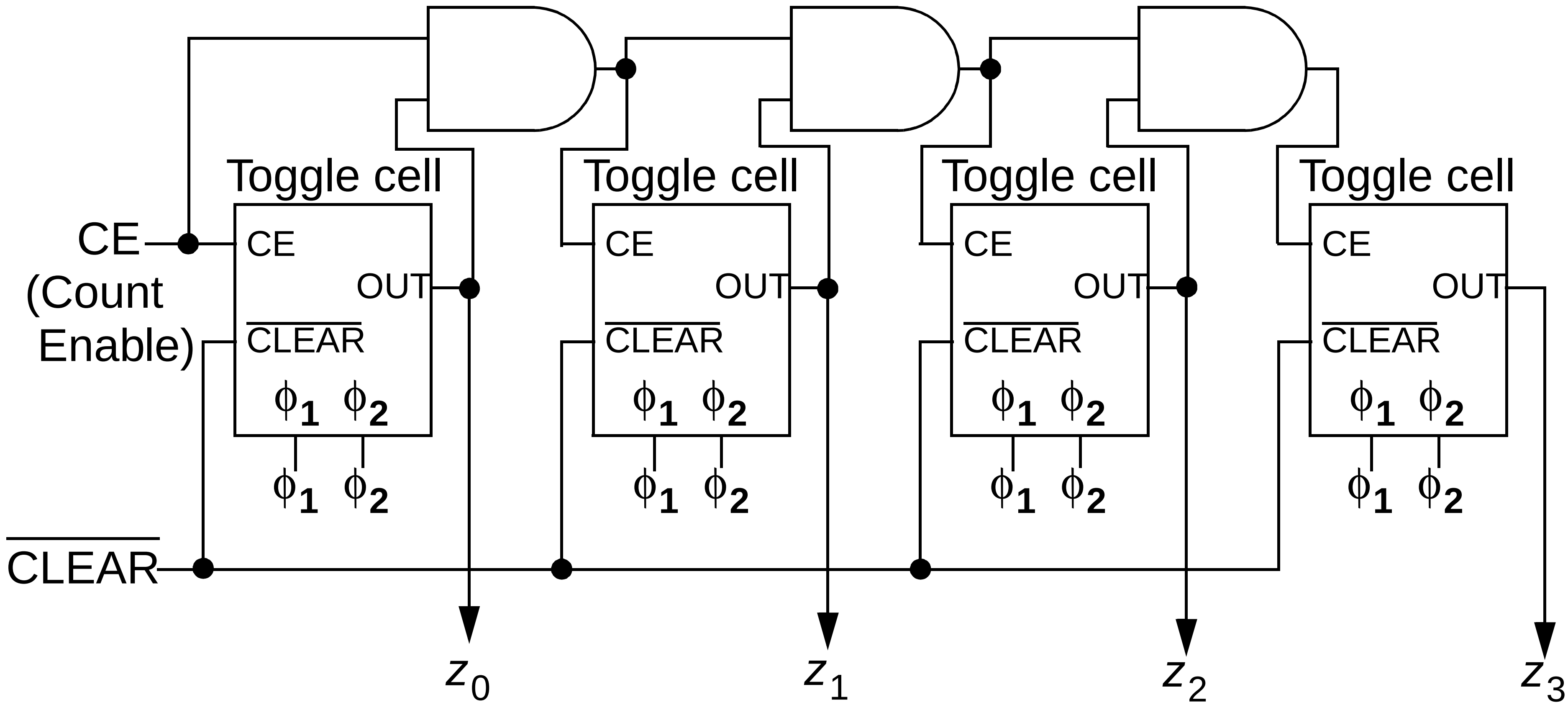


- Notice that the previous toggle cell is connected to the clock input of the next cell. This causes the bits to ripple through the counter.

COUNTERS

SYNCHRONOUS COUNTER

- Below is an example 4-bit synchronous counter using toggle cells.

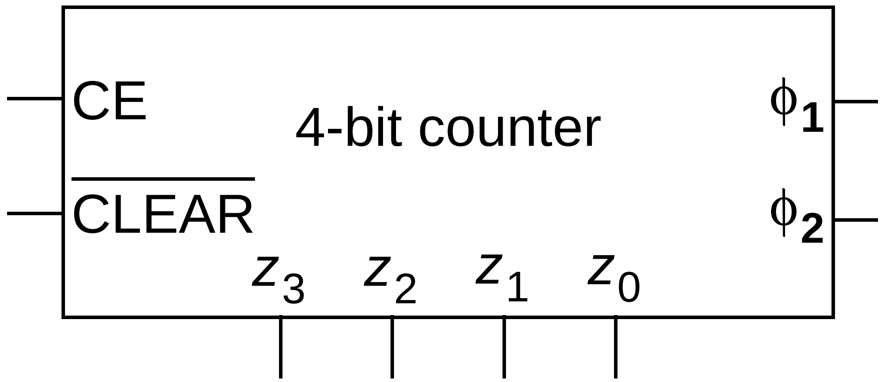


- Notice that clock is sent to all toggle cells.
- A simplified form is in Figure 5-11, pp. 269 of Mano & Kime.

COUNTERS

MORE ON MODULO-*P*

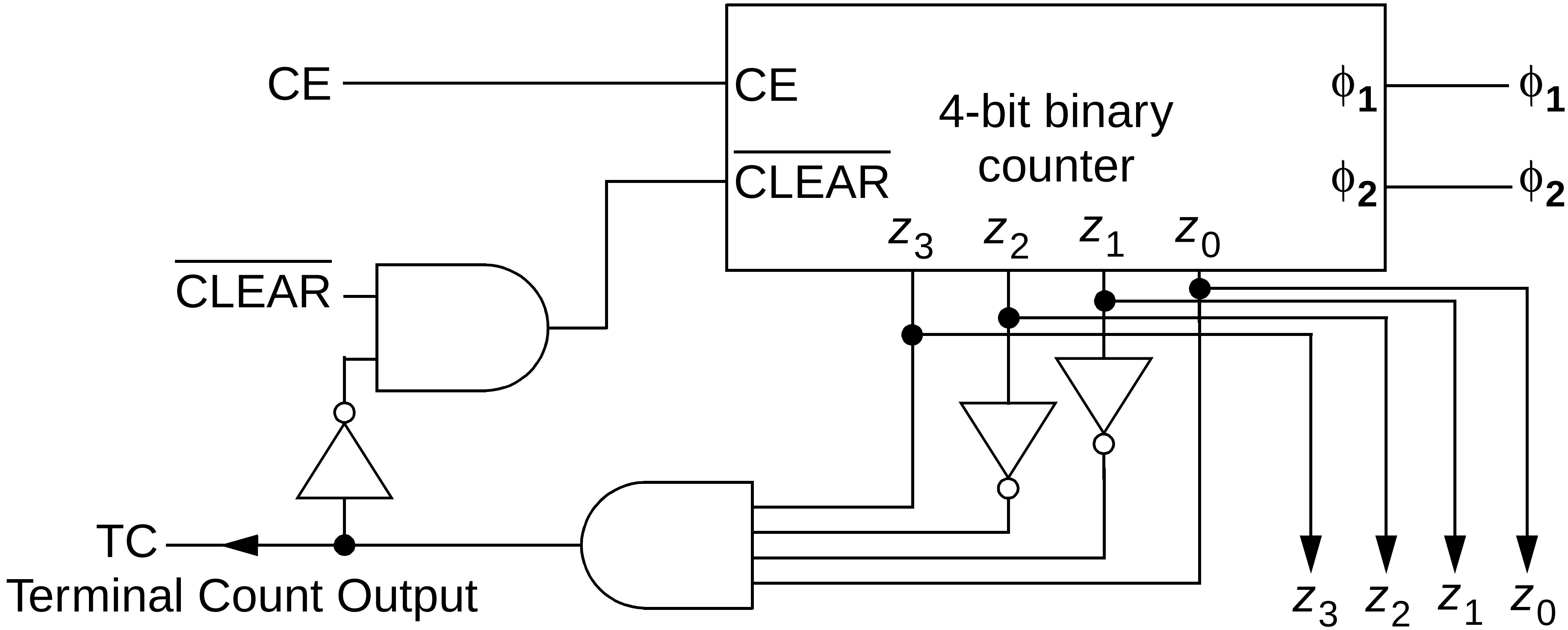
- Notice that the counters developed so far can count from 0 to $2^n - 1$ for n toggle cells.
  - Therefore, for module-p counting, the p is currently limited to 2^n.
- How about if we wish p to be a non-power of 2?
  - Need to build what can be referred to as a divide by counter.
  - Given the following counter block, a general modulo-p counter can be constructed by clearing the counter after the desired maximum value.



COUNTERS

BCD COUNTER (MODULO-10)

- To illustrate general modulo-*p* counters, consider the following implementation of a single digit decimal counter using BCD.

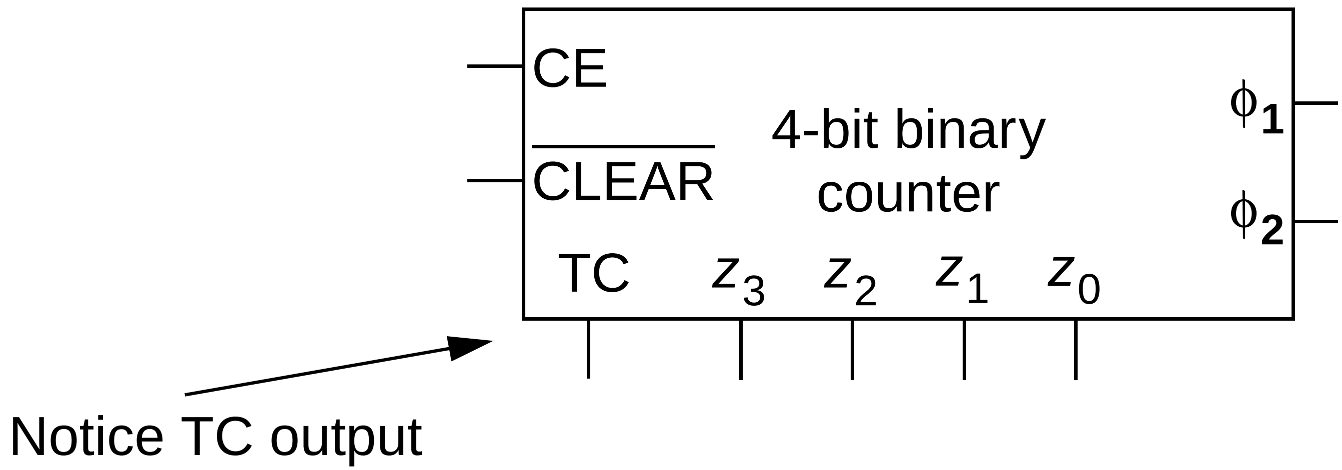


- Notice that the counter is cleared after a value of 9 (**1001**).

COUNTERS

TERMINAL COUNT (TC)

- The previous BCD counter was built by deriving a terminal count (TC) output signal.
- A terminal count output signal for any counter can be useful, so, we will be included in general block diagram for a binary counter.



- In this 4-bit binary counter example, TC=**1** only when the output is **1111**.

COUNTERS

CASCADING COUNTERS

- With a terminal count output (TC), counters can be easily cascaded together to form larger counters.
  - For instance, an 8-bit binary counter can be formed as follows.