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Lecture 15: October 22, 2001

Reminder:

20 Minute Quiz Wed. Oct. 31 in class

2nd Midterm Wed. Nov. 7 in class

Logic with a State Dependent Device

A) State Dependent Device I_{OUT} vs. V_{OUT}

B) Load Line Analysis for Logic Levels

C) Voltage Transfer Characteristics

VTC = plot of V_{OUT} vs. V_{IN}

D) 42 Pull Down (42PD) Device and Logic

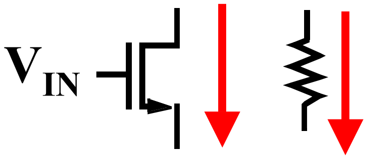
Reading:

Schwarz and Oldham pp. 593-595, 604-606

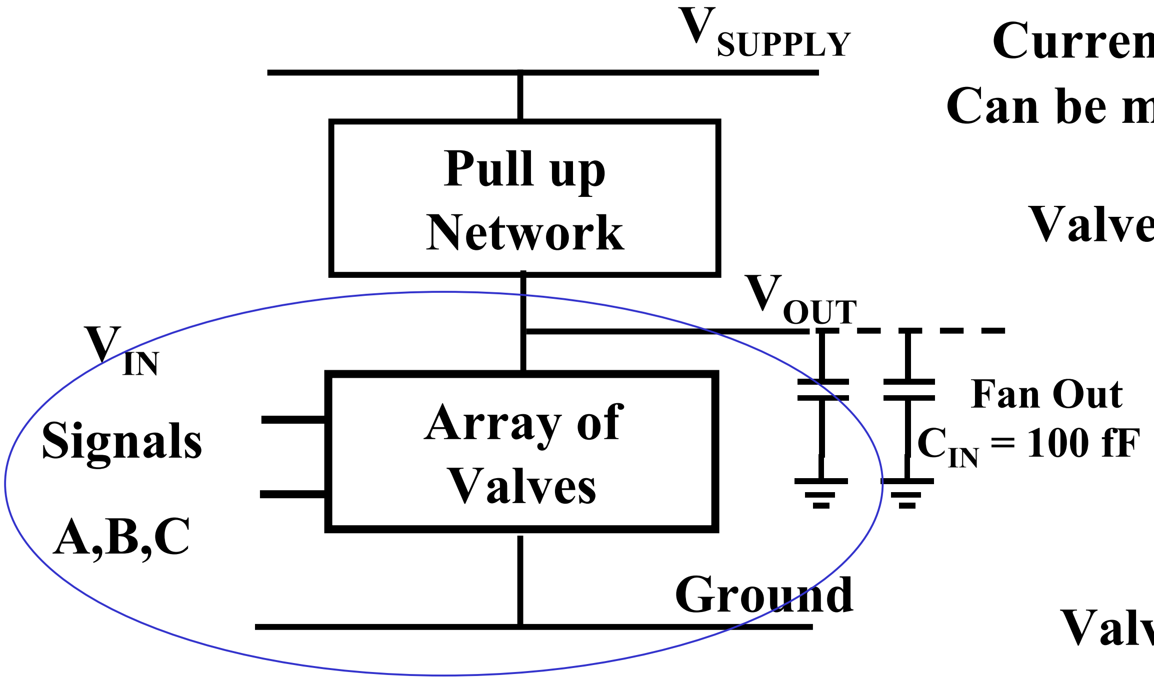
(read for graphs and not physics)

Logic Gates – How are they built in practice?

A Valve is a Transistor



Current flows when V_{IN} is high
Can be modeled by a 10kΩ resistor



V_{SUPPLY}

Pull up Network

V_{OUT}

V_{IN}

Signals

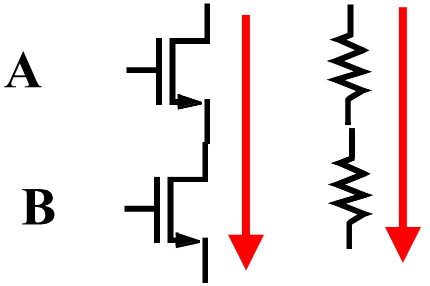
A,B,C

Array of Valves

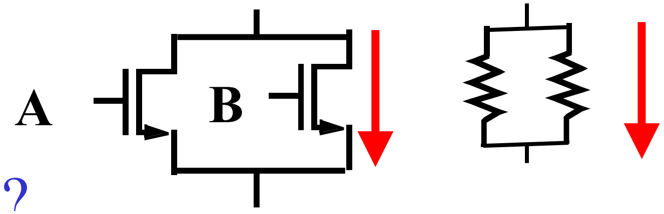
Fan Out
C_{IN} = 100 fF

Ground

Valves in Series => NAND



Valves in Parallel => NOR



What goes in this box?

How does it affect digital performance?

Digital Logic from State-Dependent Three-Terminal Devices

Three-terminal devices such as MOS transistors have characteristics (such as I_{OUT} vs. V_{OUT} curves) on the output side that can be programmed by changing signals on the input side (such as the input voltage).

The input can thus be viewed as changing or programming the 'State' of the output of the device.

Three-terminal devices whose 'State' can be programmed can be used to make digital logic devices for computers that respond to input signals.

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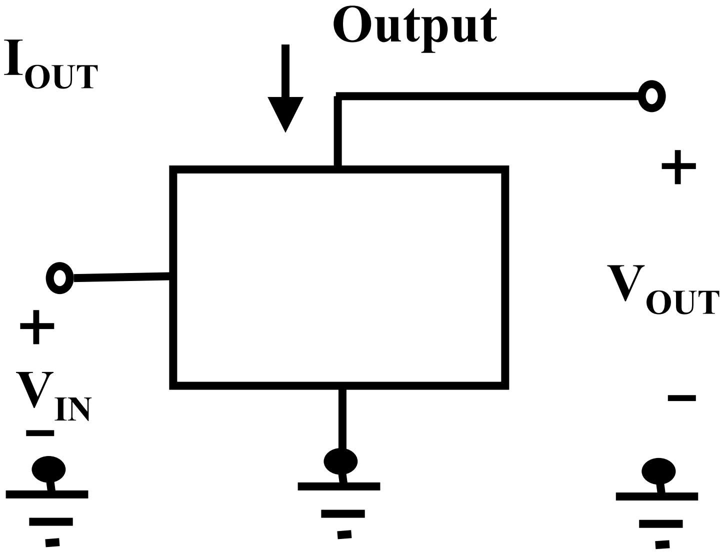
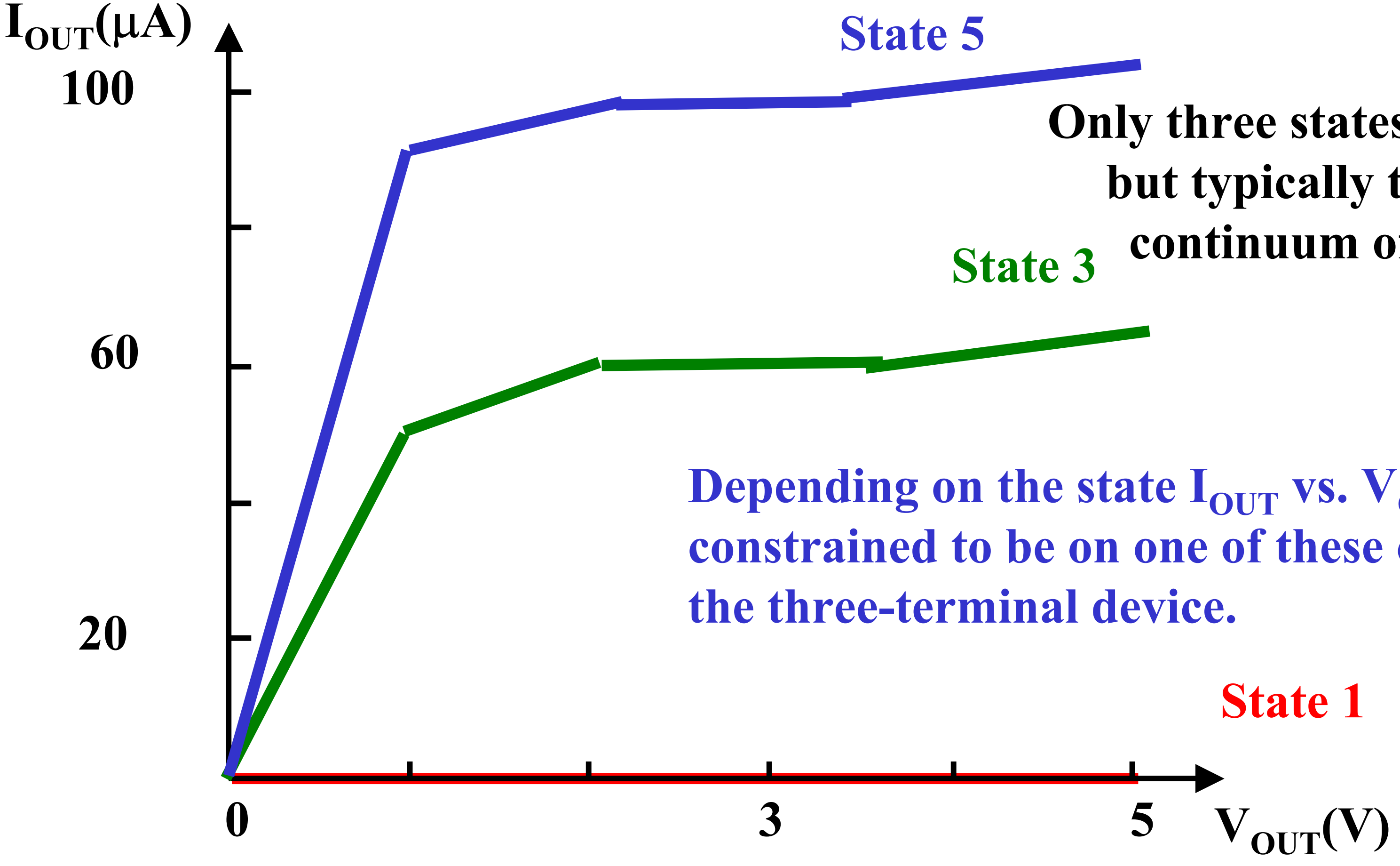
State-Dependent Three-Terminal Device Element



Input for Control
Signal to set the State

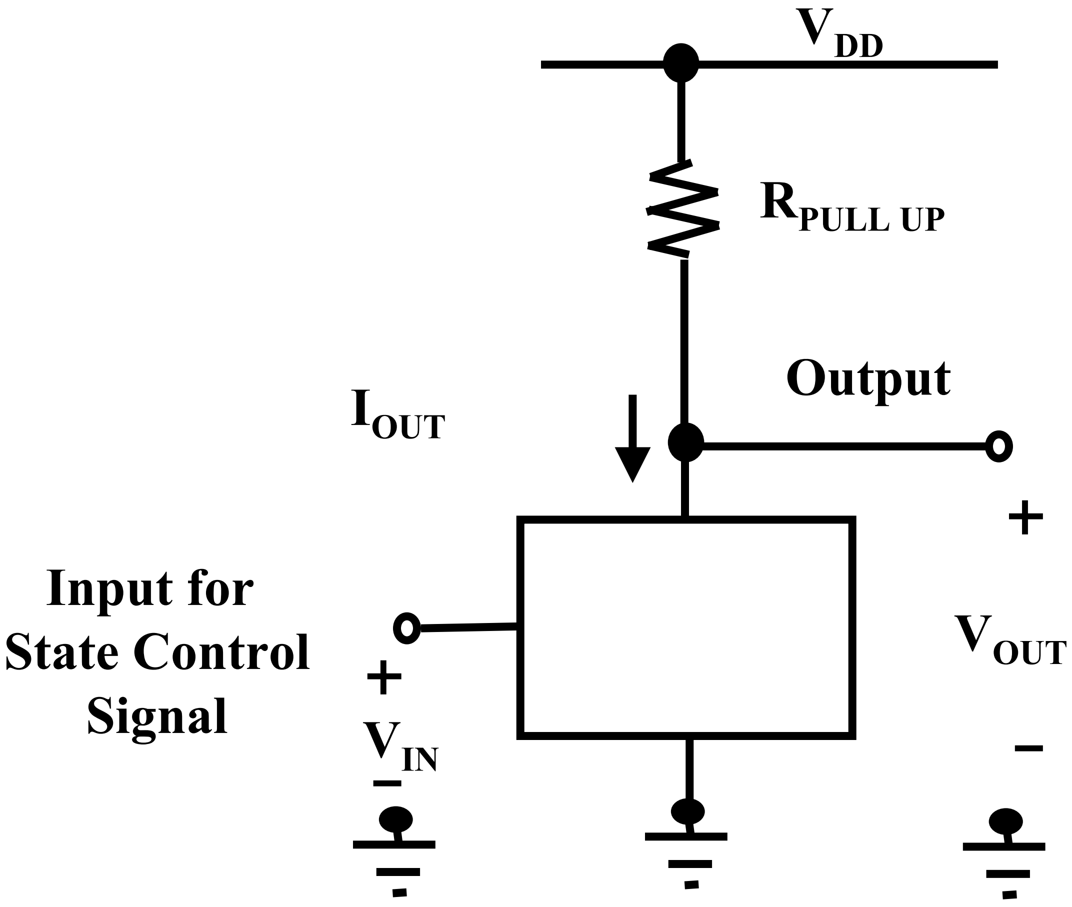
State-Dependent Device I_{OUT} vs. V_{OUT}



Only three states are shown but typically there is a continuum of states.

Depending on the state I_{OUT} vs. V_{OUT} is constrained to be on one of these curves by the three-terminal device.

Three-Terminal Device Logic Circuit



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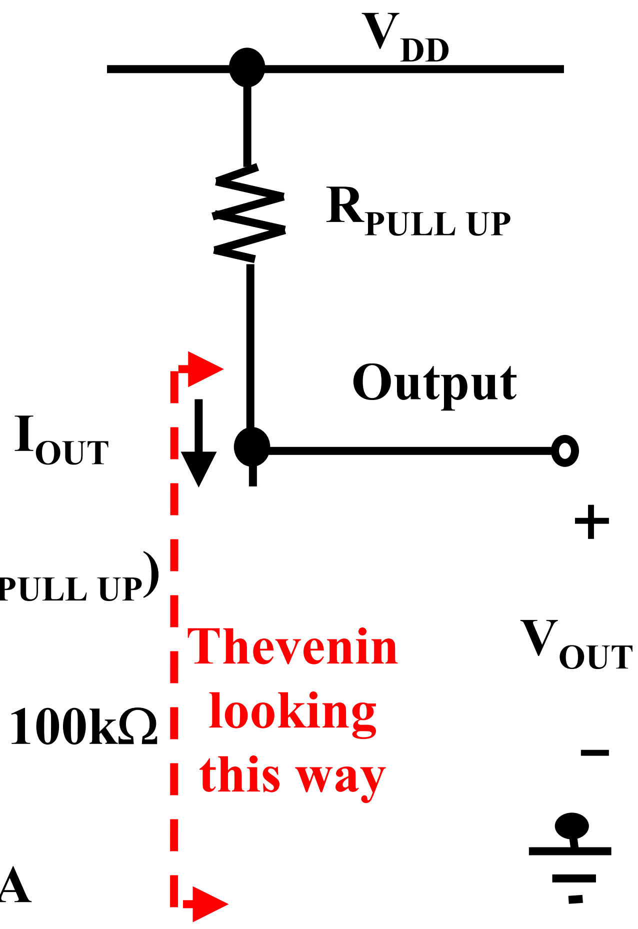
Thevenin Model For Pull-Up Device



$V_{THEVENIN} = V_{DD}$

$I_{OUT\ SHORT\ CIRCUIT} = (V_{DD}/R_{PULL\ UP})$

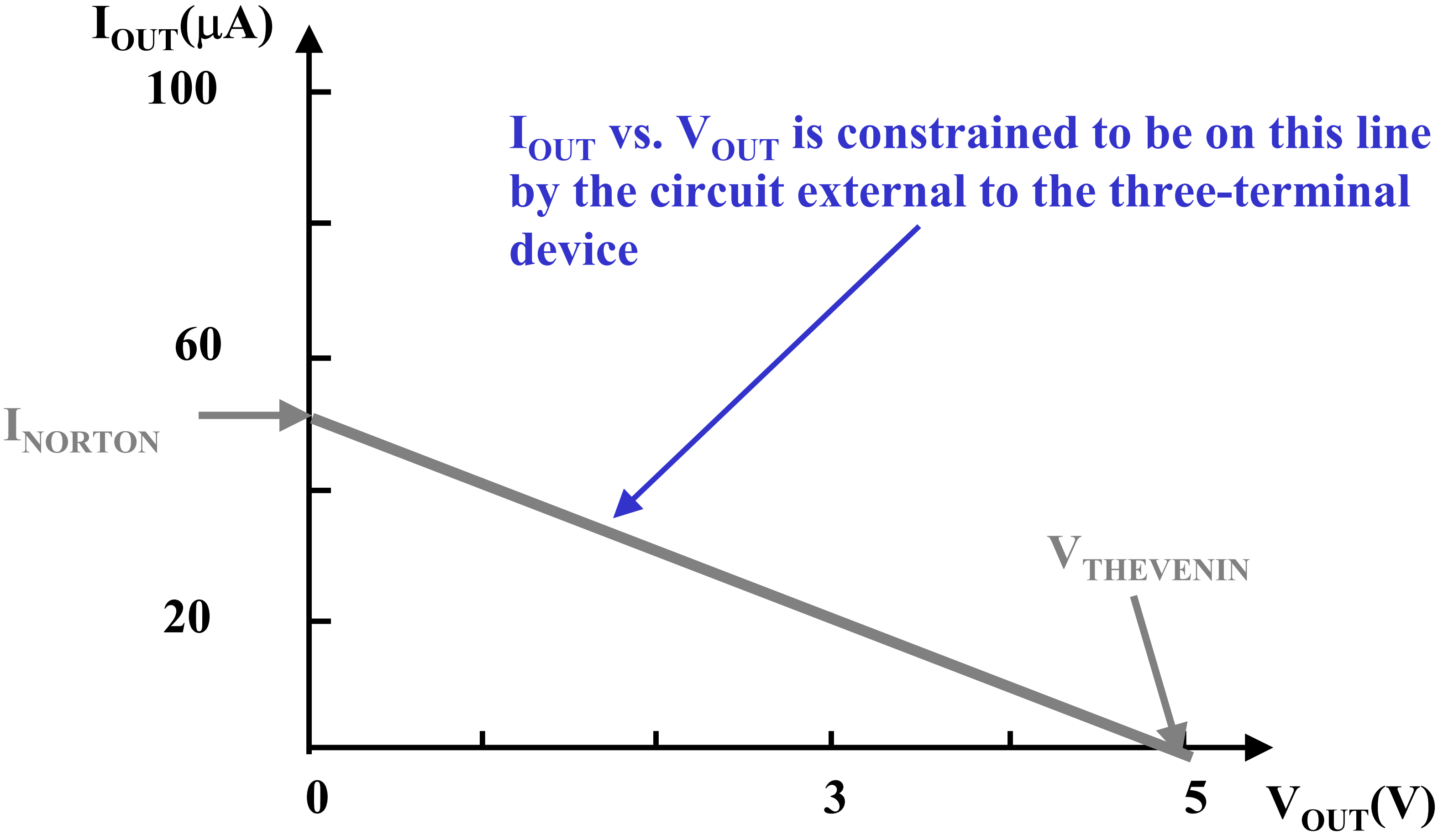
Example:

$V_{DD} = 5V$ and $R_{PULL\ UP} = 100k\Omega$

$V_{THEVENIN} = 5V$

$I_{OUT\ SHORT\ CIRCUIT} = 50\ \mu A$

Thevenin Model For Pull-Up Device



I_{OUT} vs. V_{OUT}
For the Pull-Up Resistor and V_{DD}

I_{OUT} vs. V_{OUT} is constrained to be on this line by the circuit external to the three-terminal device

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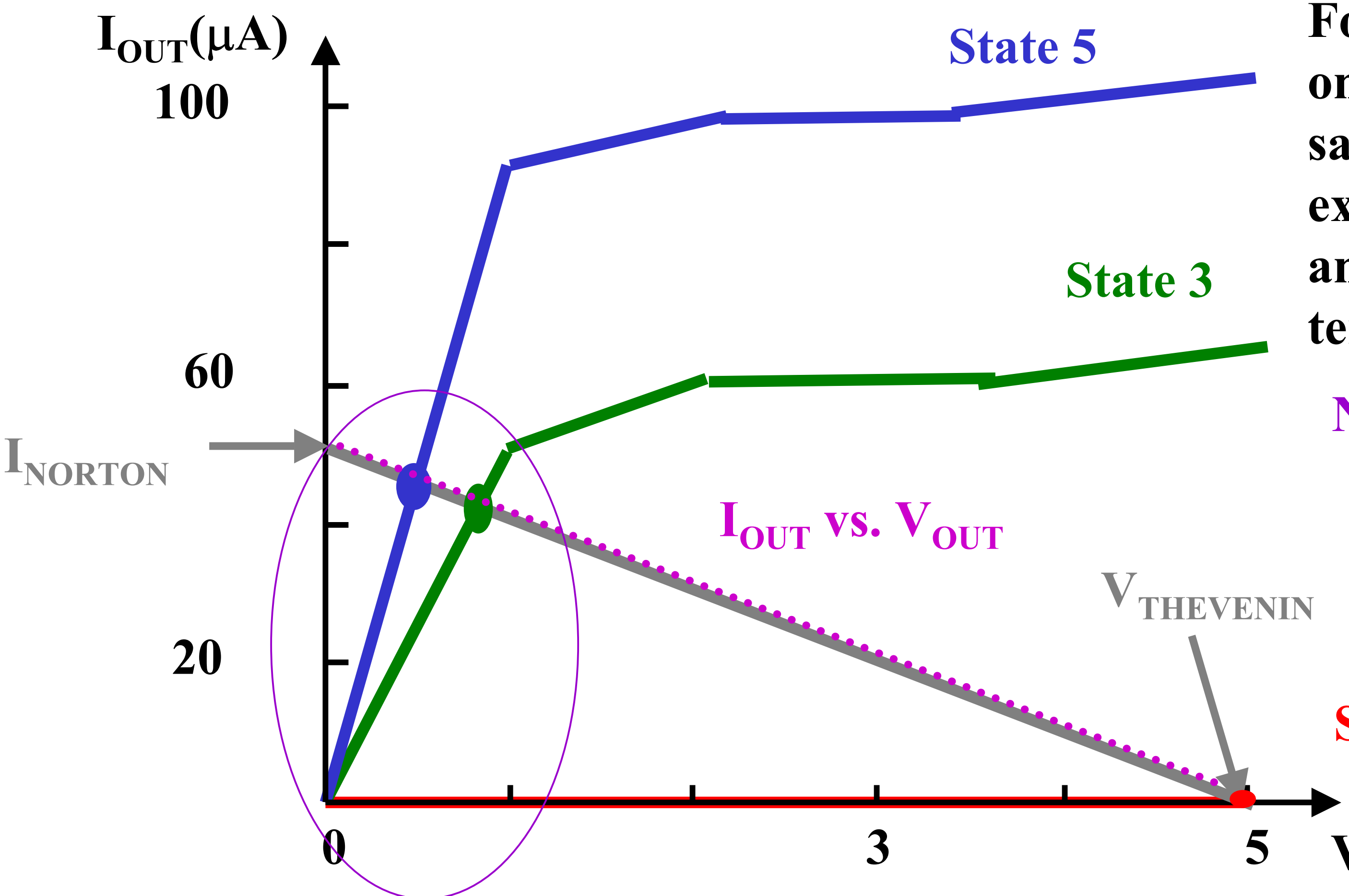
Composite Current Plot for the Logic Circuit

Three-Terminal Device Plus Load Line for the Pull-Up Device



For a given state only one point satisfies both the external circuit and the three-terminal device

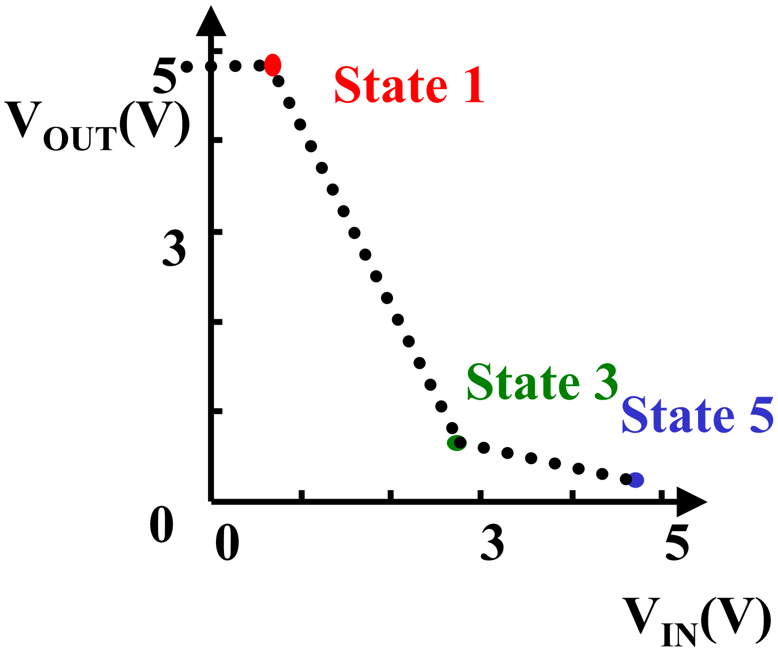
Note that when V_{OUT} is low current flows and power is consummed

State 1

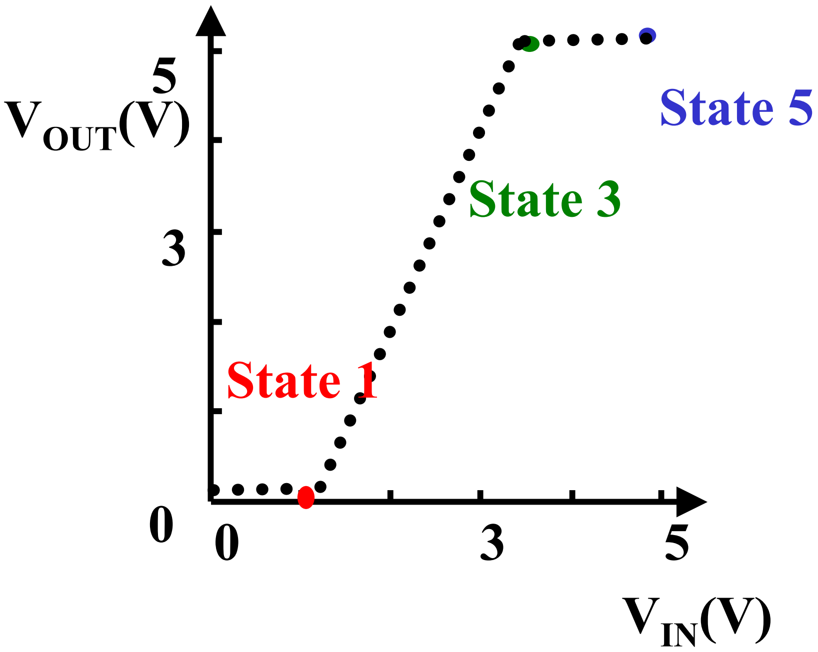
Voltage Transfer Function: V_{OUT} vs. V_{IN}

The V_{OUT} vs. V_{IN} characteristic is another view of the logic gate that is used to determine the inverting and noninverting nature of a gate.

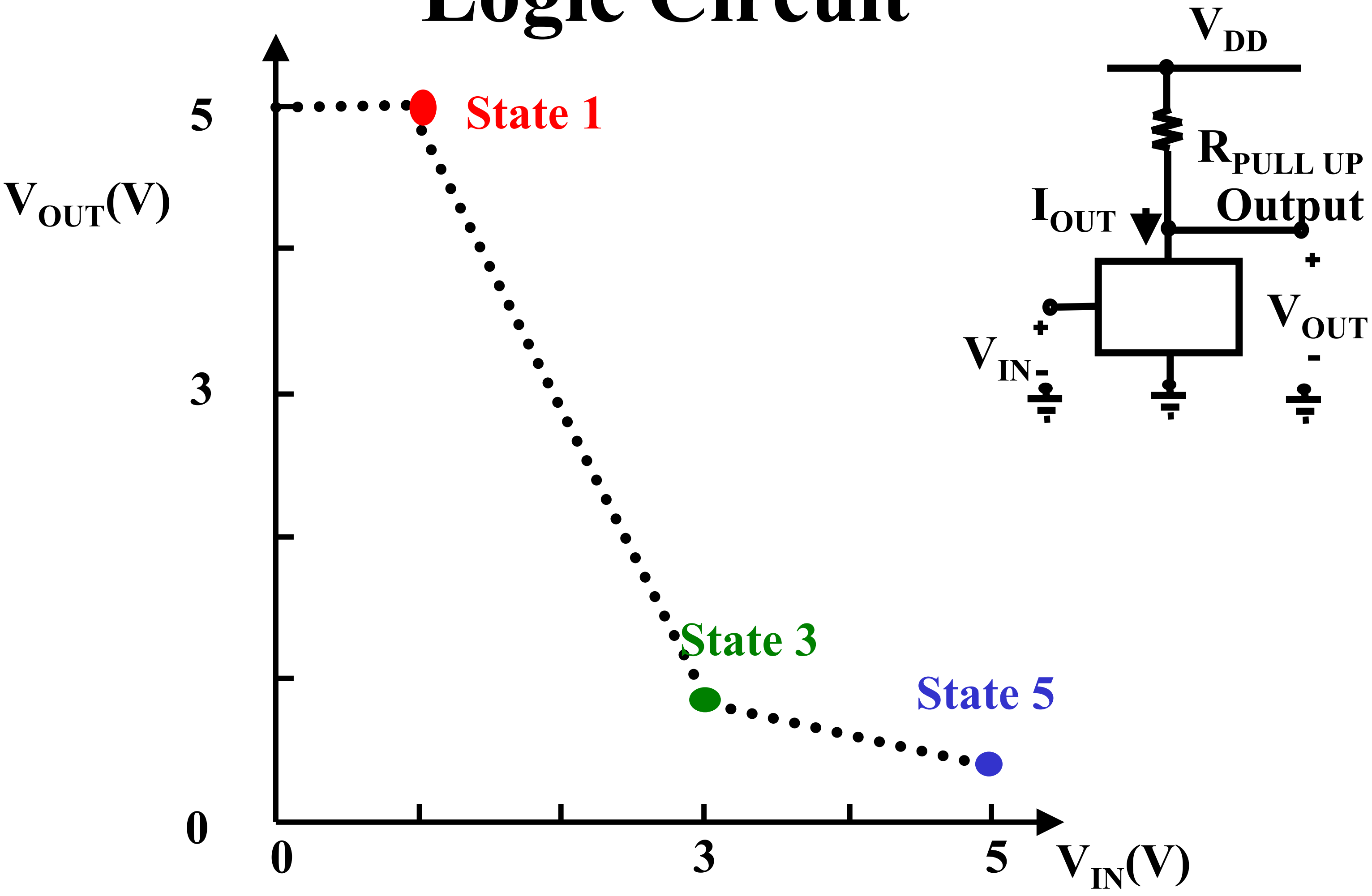
Inverting type



Noninverting type

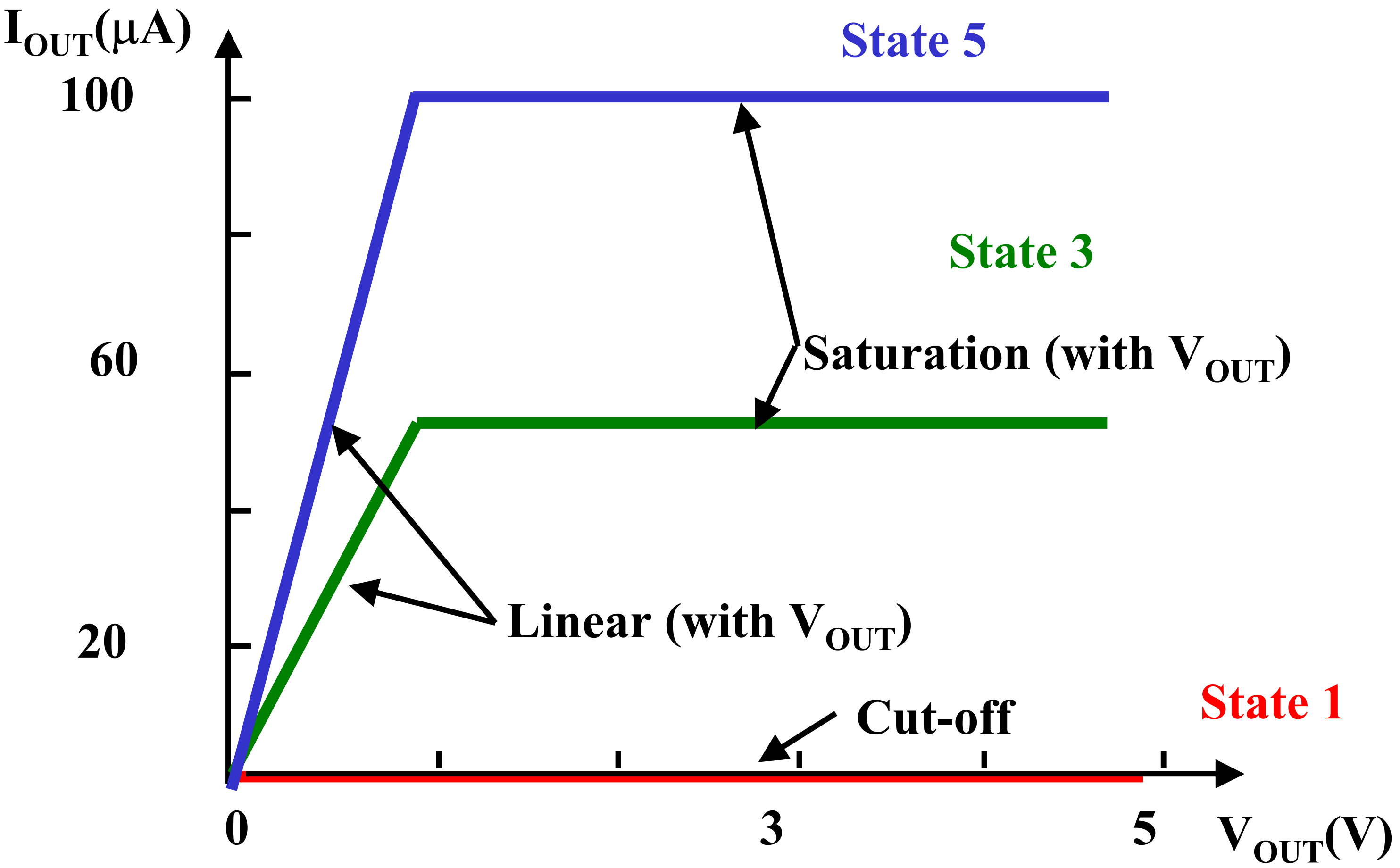


Voltage Transfer Function for the Logic Circuit



42Pull-Down Device Model

I_{OUT} vs. V_{OUT}



42Pull-Down Device Equations

Describe I_{OUT} as function of V_{IN} and V_{OUT}

Values shown for V_T = 1V and k = 25 μA/V^2

Cut-off $V_{IN} \leq V_T = 1V$

$$I_{OUT} = 0$$

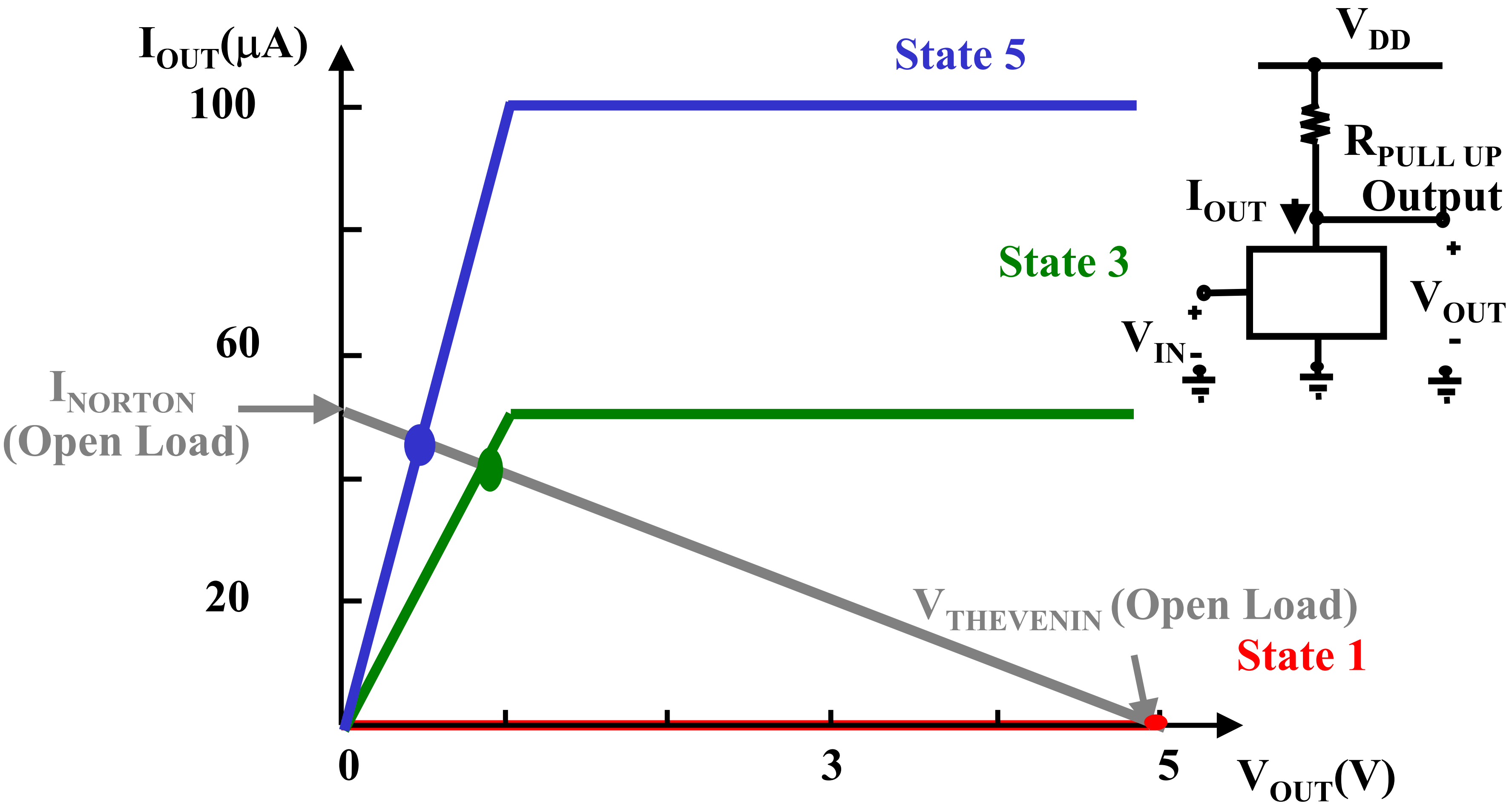
Linear (with V_{OUT}) $V_{IN} \leq V_T = 1V$ $V_{OUT} \leq V_T = 1V$

$$I_{OUT} = k\left(V_{IN} - V_T\right)V_{OUT} = 25\frac{\mu A}{V^2}\left(V_{IN} - 1\right)V_{OUT}$$

Saturation (with V_{OUT}) $V_{IN} \leq V_T = 1V$ $V_{OUT} \geq V_T = 1V$

$$I_{OUT} = k\left(V_{IN} - V_T\right)V_T = 25\frac{\mu A}{V}\left(V_{IN} - 1\right)V_T$$

Composite Current Plot for the 42PD Circuit



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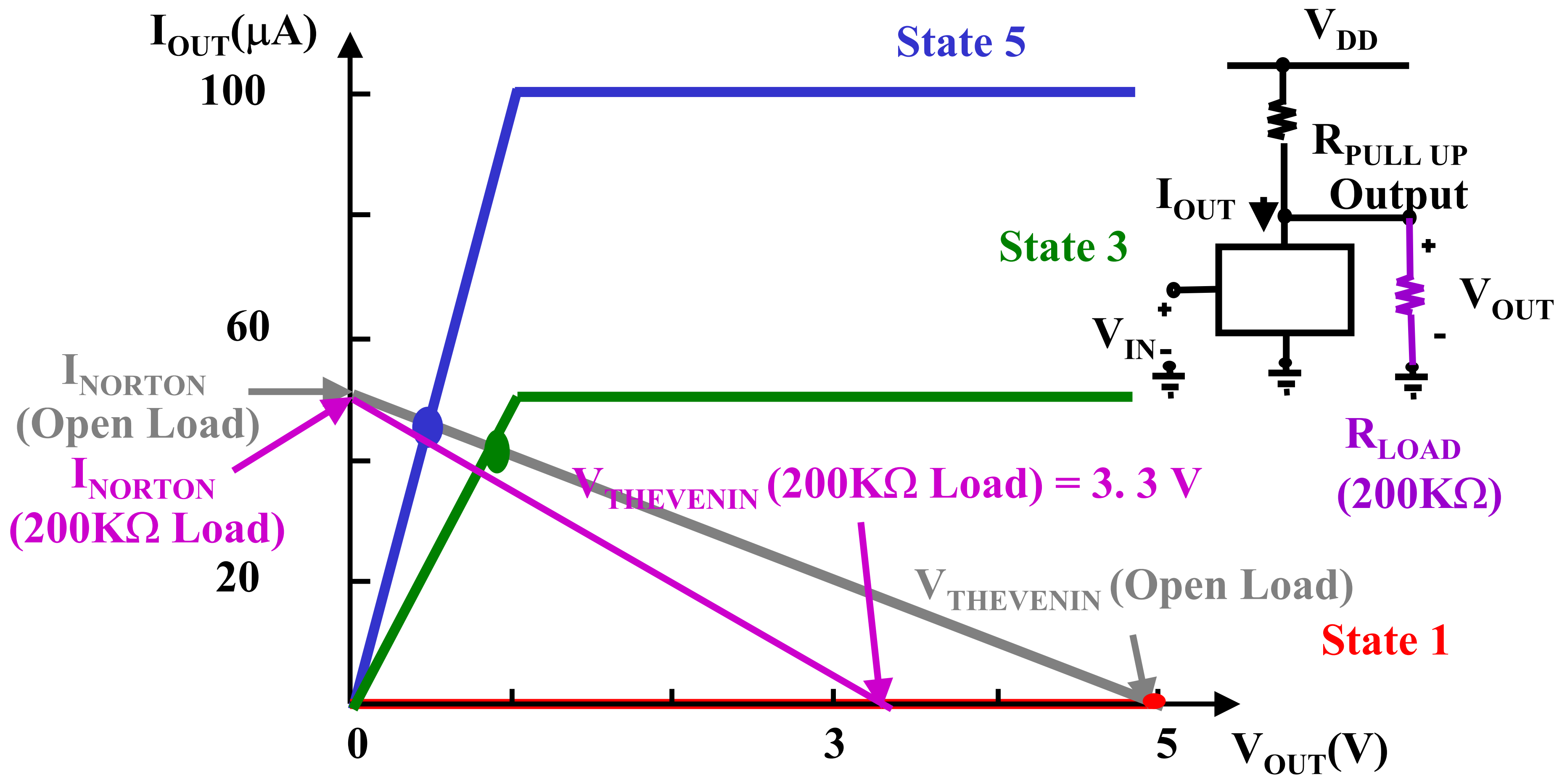
Composite Current Plot for the 42PD Circuit with 200kΩ Load to Ground



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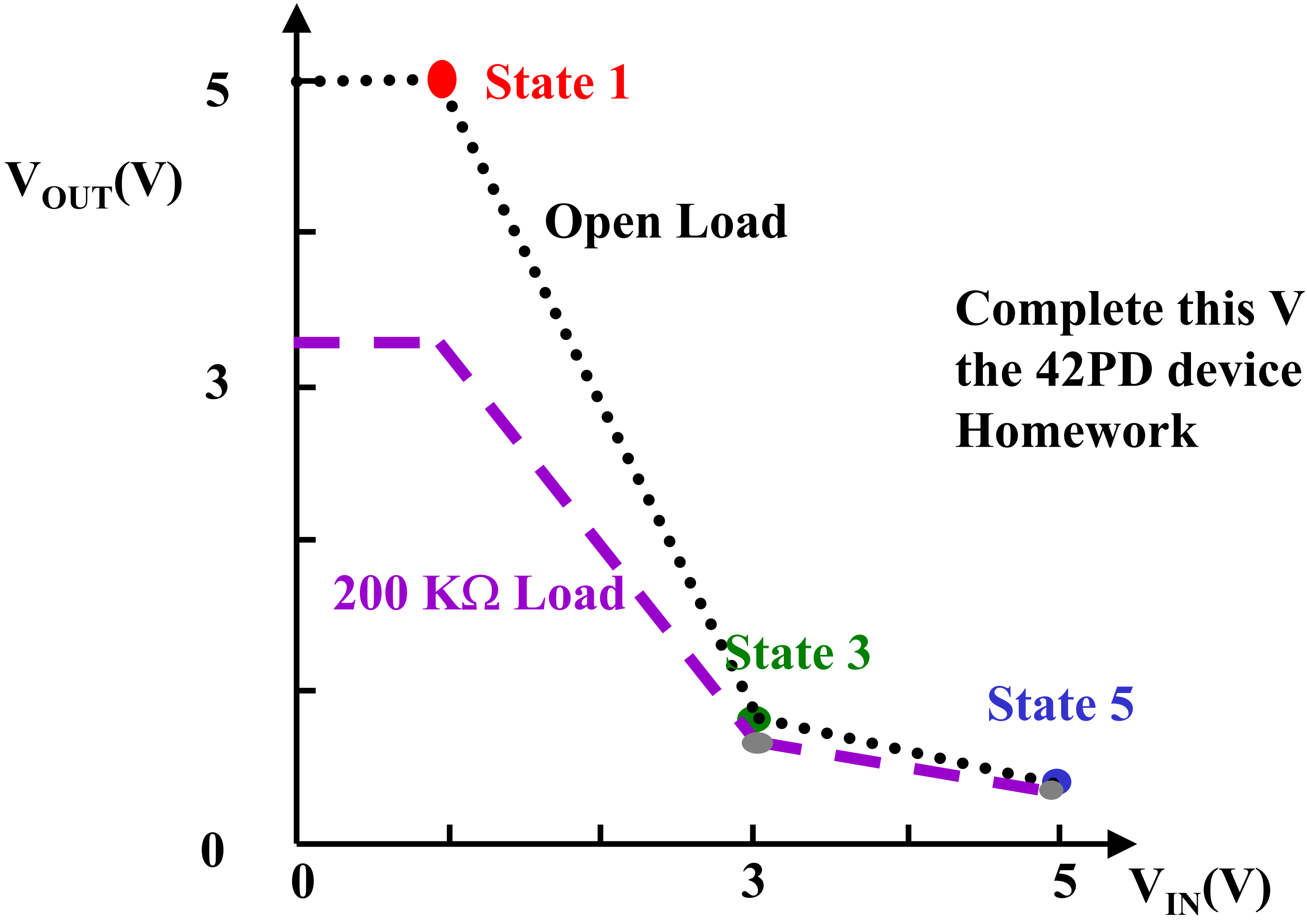
Voltage Transfer Function for the 42PD Logic Circuit w/wo Load



Complete this VTC for the 42PD device in the Homework