EEL 4744

Menu

- A/D-D/A Conversion Processes
  - >Example: "*Grandma Singing Hymns*"
- Digital Signal Processing
- Analog-to-Digital Conversion
  - >A/D Conversion Methods
- Operational Amplifier in D/A & A/D
- Digital-to-Analog

1

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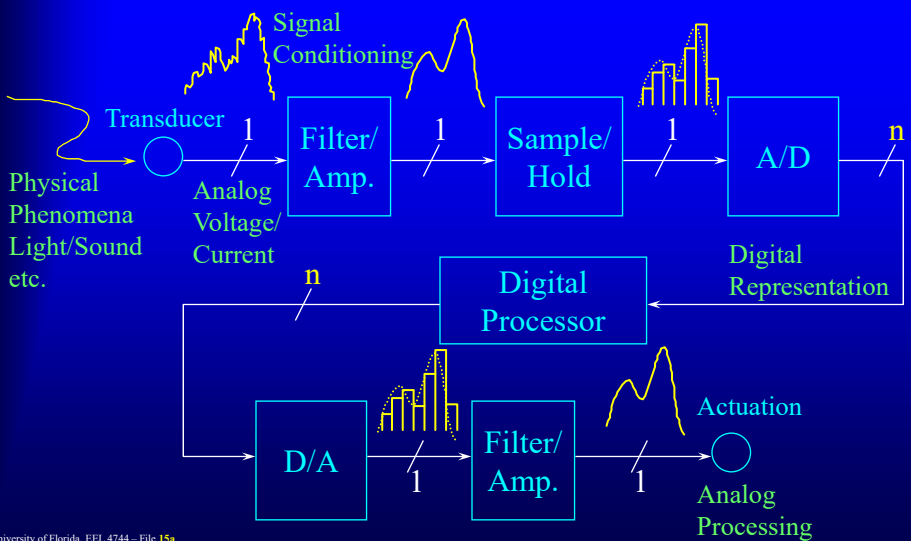
A/D and D/A Conversion Process



2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DSP (Digital Signal Processing) in ECE
• Discussion on Digital Signal Processing
> Analog filters introduced in (EEL 3112)
> Analog Filter Design (EEL 3308: Electronic Circuits 1), i.e., s-plane design
> Digital Analysis of Signals (EEL 3135: Intro to [Discrete-Time] Signals & Systems), i.e., z-plane design
> Digital Filtering (Analog-->Digital) (EEL 4712: Digital Design, EEE 4511: Real-time DSP Applications, 4750: Intro to DSP, EEE 5502: Foundations of Digital Signal Processing, 6503: Digital Filtering)
> Implementation as a Recursive Program (CE Stuff)
> Advantages of Digital Signal Processing (4511 & 4750)
• The use of D-A/A-D and Digital Processors allows computer engineers to create digital solutions to many engineering problems
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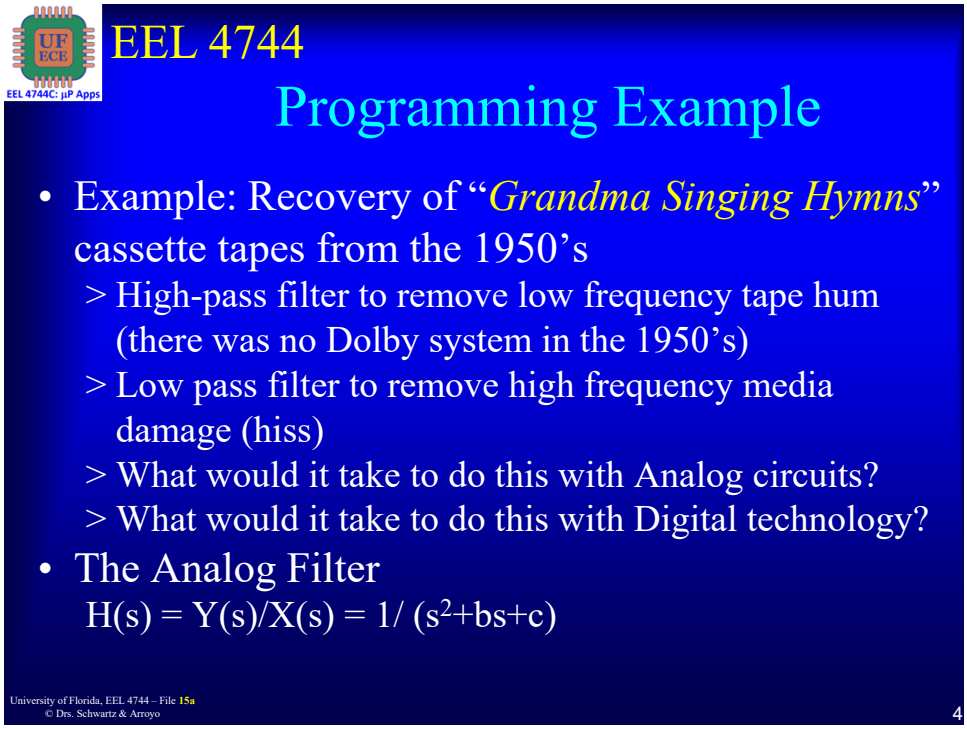
EEL 4744
Programming Example
• Example: Recovery of "Grandma Singing Hymns" cassette tapes from the 1950's
> High-pass filter to remove low frequency tape hum (there was no Dolby system in the 1950's)
> Low pass filter to remove high frequency media damage (hiss)
> What would it take to do this with Analog circuits?
> What would it take to do this with Digital technology?
• The Analog Filter
H(s) = Y(s)/X(s) = 1/ (s2+bs+c)
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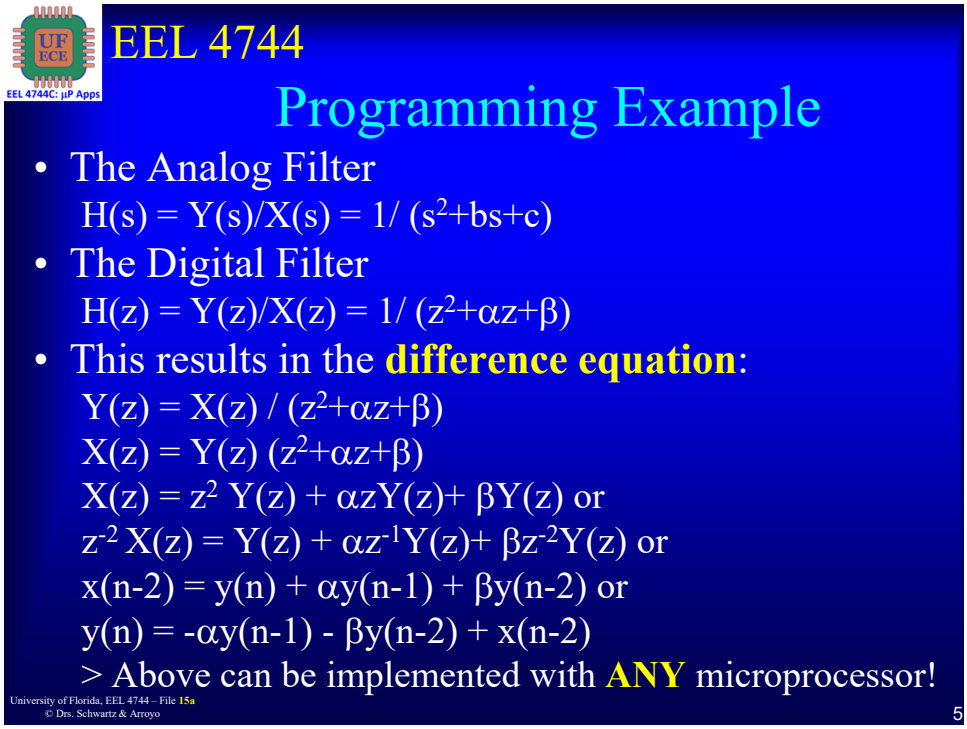
EEL 4744
Programming Example
• The Analog Filter
H(s) = Y(s)/X(s) = 1/ (s²+bs+c)
• The Digital Filter
H(z) = Y(z)/X(z) = 1/ (z²+αz+β)
• This results in the difference equation:
Y(z) = X(z) / (z²+αz+β)
X(z) = Y(z) (z²+αz+β)
X(z) = z² Y(z) + αzY(z)+ βY(z) or
z⁻² X(z) = Y(z) + αz⁻¹Y(z)+ βz⁻²Y(z) or
x(n-2) = y(n) + αy(n-1) + βy(n-2) or
y(n) = -αy(n-1) - βy(n-2) + x(n-2)
> Above can be implemented with ANY microprocessor!
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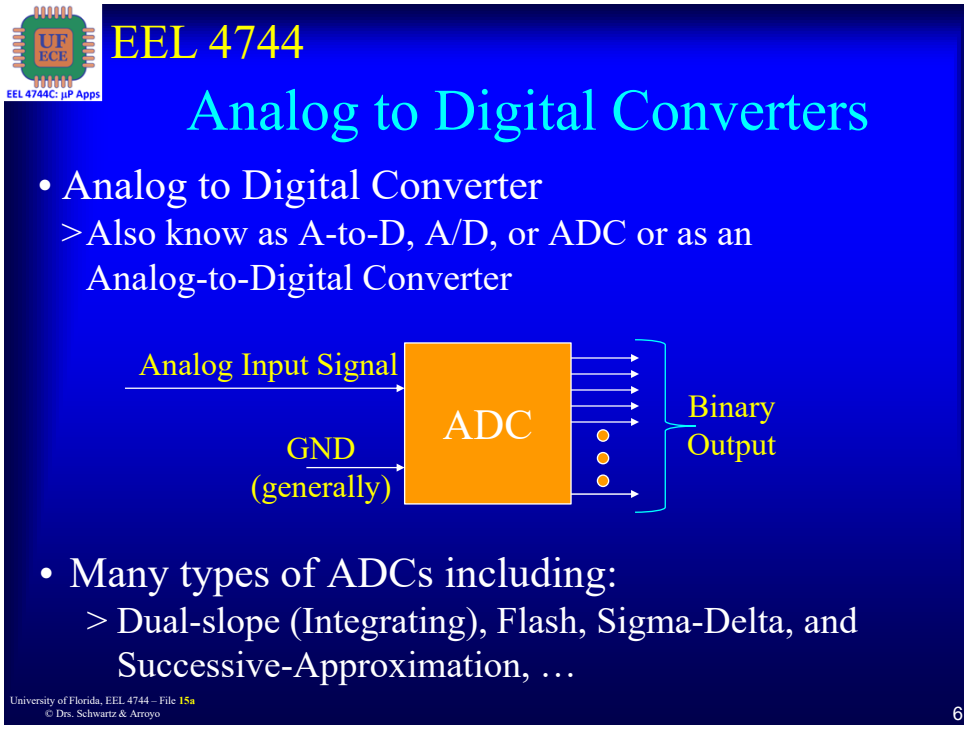
EEL 4744
Analog to Digital Converters
• Analog to Digital Converter
>Also know as A-to-D, A/D, or ADC or as an
Analog-to-Digital Converter
Analog Input Signal
GND
(generally)
ADC
Binary
Output
• Many types of ADCs including:
> Dual-slope (Integrating), Flash, Sigma-Delta, and
Successive-Approximation, …
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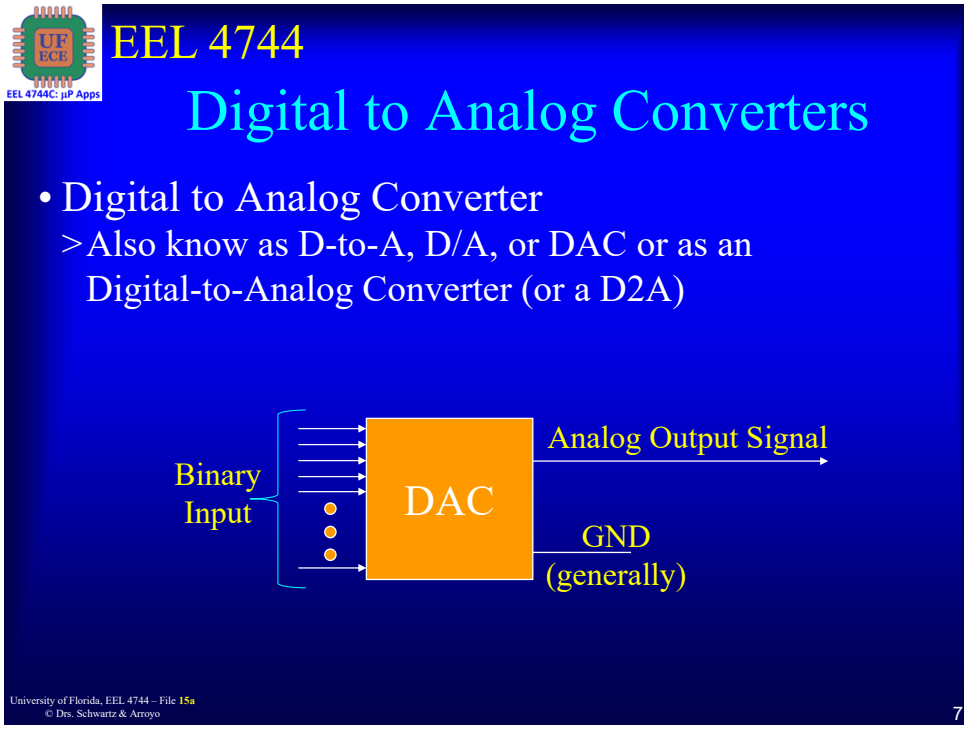
EEL 4744
EEL 4744C: µP Apps
Digital to Analog Converters
• Digital to Analog Converter
> Also know as D-to-A, D/A, or DAC or as an Digital-to-Analog Converter (or a D2A)
Binary Input
DAC
Analog Output Signal
GND (generally)
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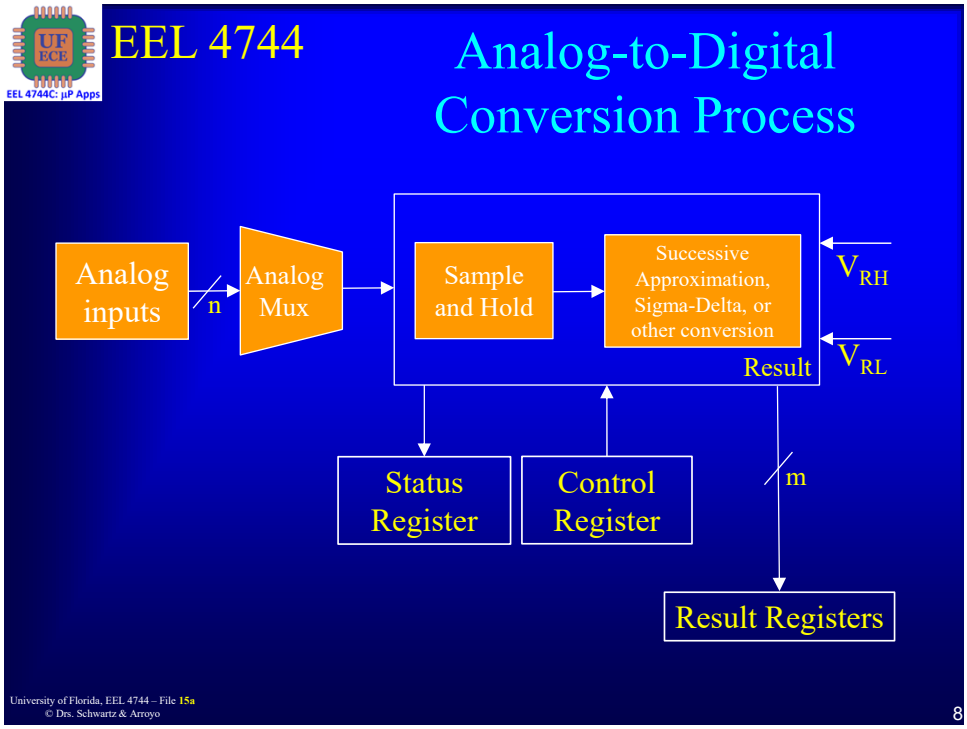
EEL 4744
EEL 4744C: µP Apps
Analog-to-Digital Conversion Process
Analog inputs
n
Analog Mux
Sample and Hold
Successive Approximation, Sigma-Delta, or other conversion
Result
V_{RH}
V_{RL}
Status Register
Control Register
m
Result Registers
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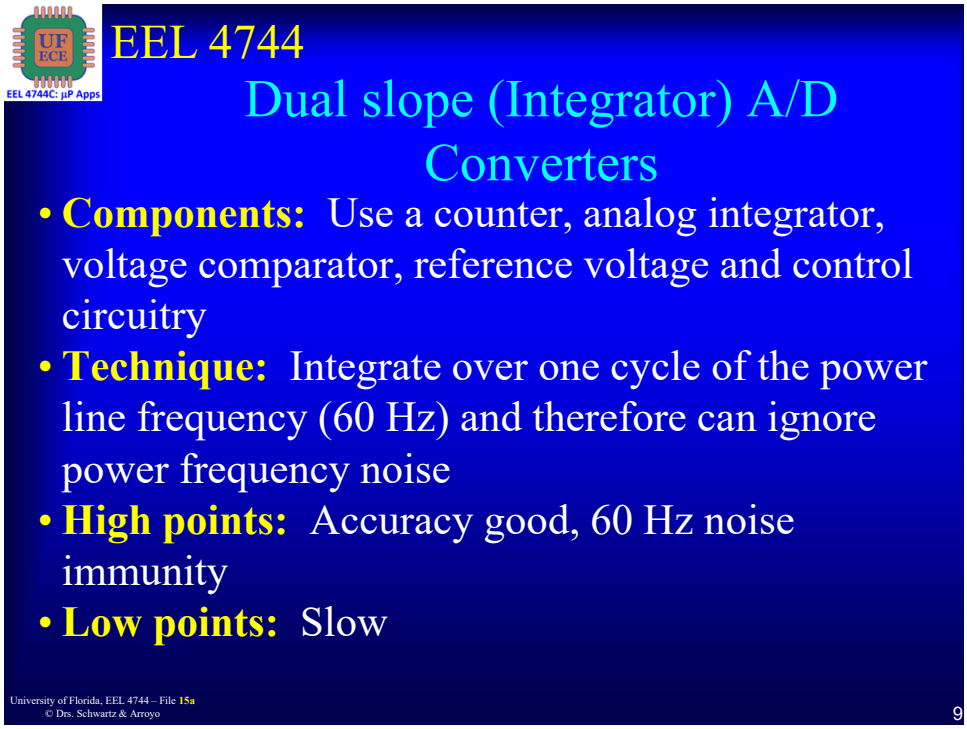
EEL 4744
Dual slope (Integrator) A/D Converters
• Components: Use a counter, analog integrator, voltage comparator, reference voltage and control circuitry
• Technique: Integrate over one cycle of the power line frequency (60 Hz) and therefore can ignore power frequency noise
• High points: Accuracy good, 60 Hz noise immunity
• Low points: Slow
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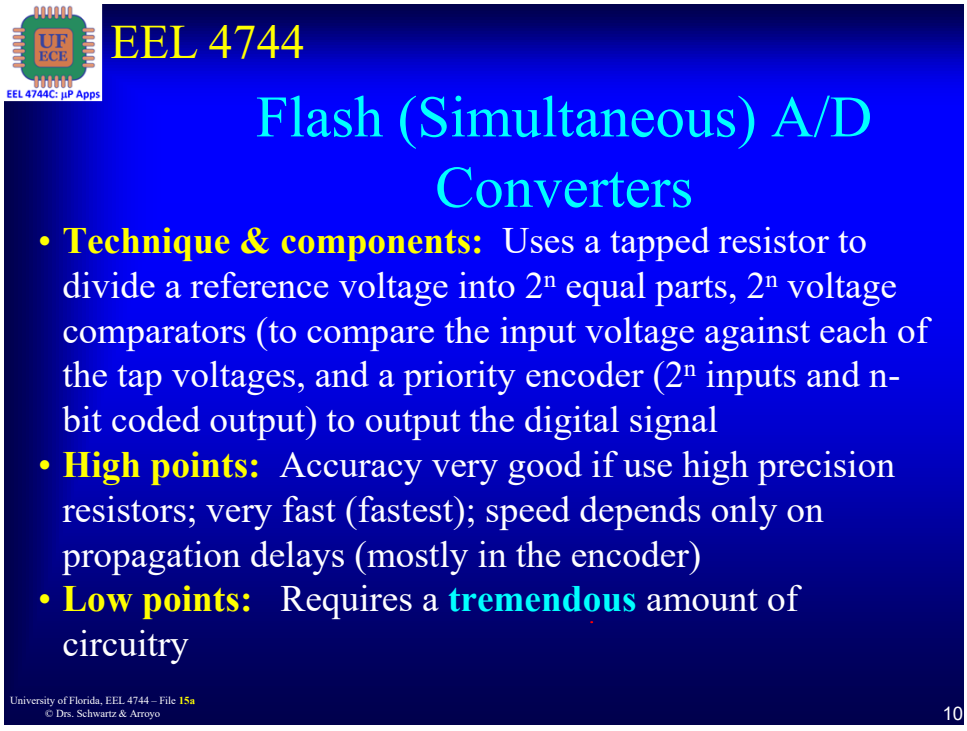
EEL 4744
Flash (Simultaneous) A/D Converters
• Technique & components: Uses a tapped resistor to divide a reference voltage into 2^n equal parts, 2^n voltage comparators (to compare the input voltage against each of the tap voltages, and a priority encoder (2^n inputs and n-bit coded output) to output the digital signal
• High points: Accuracy very good if use high precision resistors; very fast (fastest); speed depends only on propagation delays (mostly in the encoder)
• Low points: Requires a tremendous amount of circuitry
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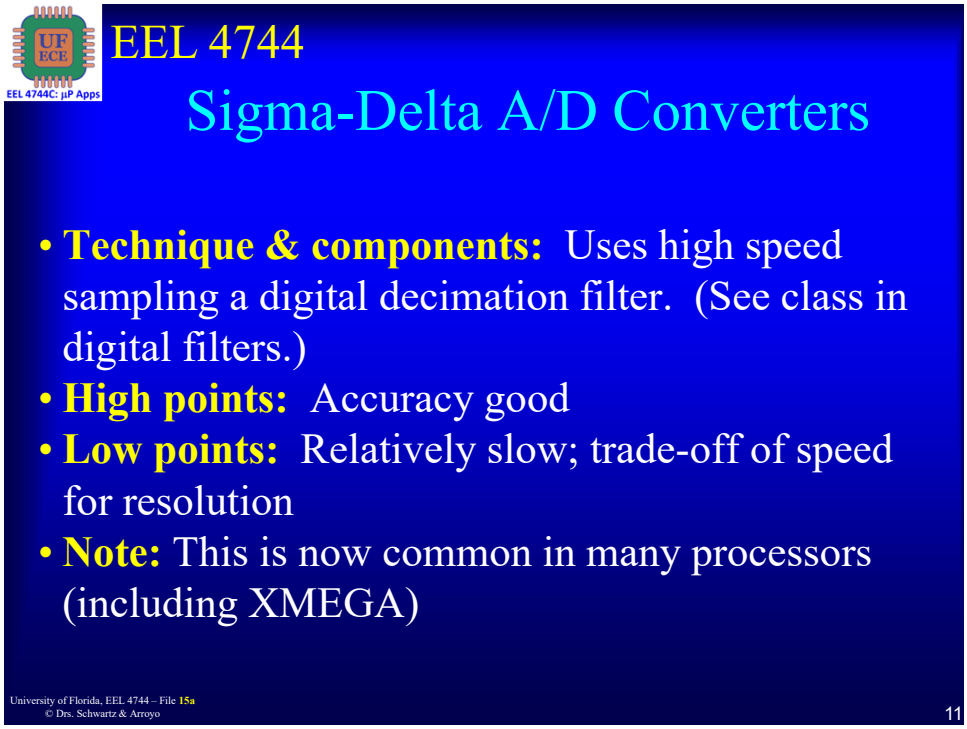
EEL 4744
Sigma-Delta A/D Converters
• Technique & components: Uses high speed sampling a digital decimation filter. (See class in digital filters.)
• High points: Accuracy good
• Low points: Relatively slow; trade-off of speed for resolution
• Note: This is now common in many processors (including XMEGA)
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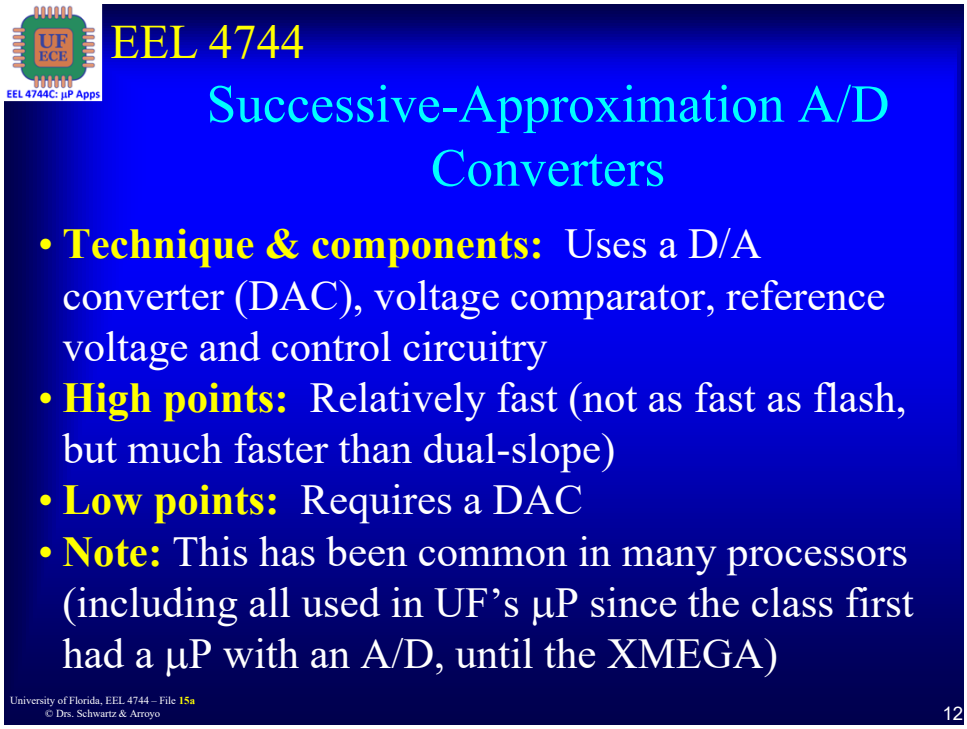
EEL 4744
Successive-Approximation A/D Converters
• Technique & components: Uses a D/A converter (DAC), voltage comparator, reference voltage and control circuitry
• High points: Relatively fast (not as fast as flash, but much faster than dual-slope)
• Low points: Requires a DAC
• Note: This has been common in many processors (including all used in UF's µP since the class first had a µP with an A/D, until the XMEGA)
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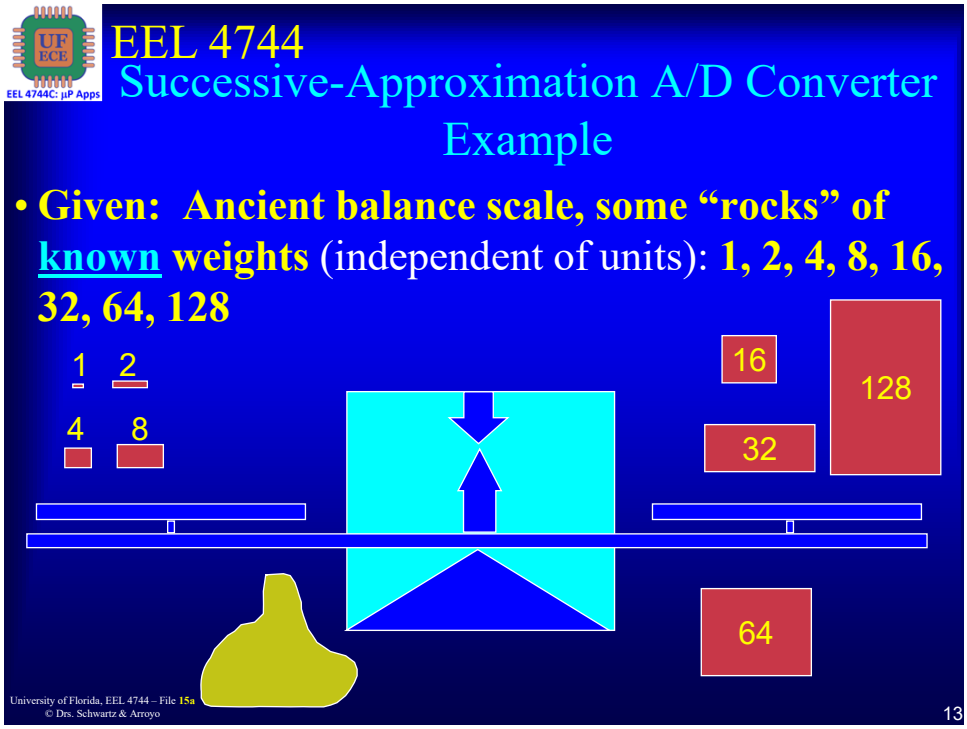
EEL 4744
Successive-Approximation A/D Converter Example
• Given: Ancient balance scale, some "rocks" of known weights (independent of units): 1, 2, 4, 8, 16, 32, 64, 128
1
2
4
8
16
32
64
128
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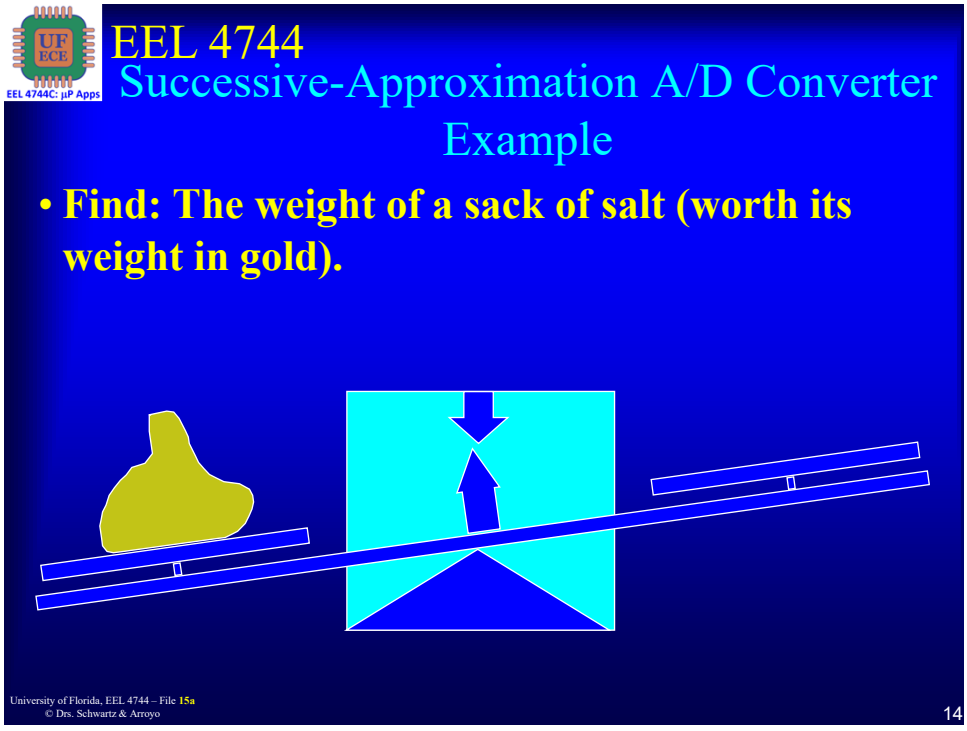
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Successive-Approximation A/D Converter Example
• Find: The weight of a sack of salt (worth its weight in gold).
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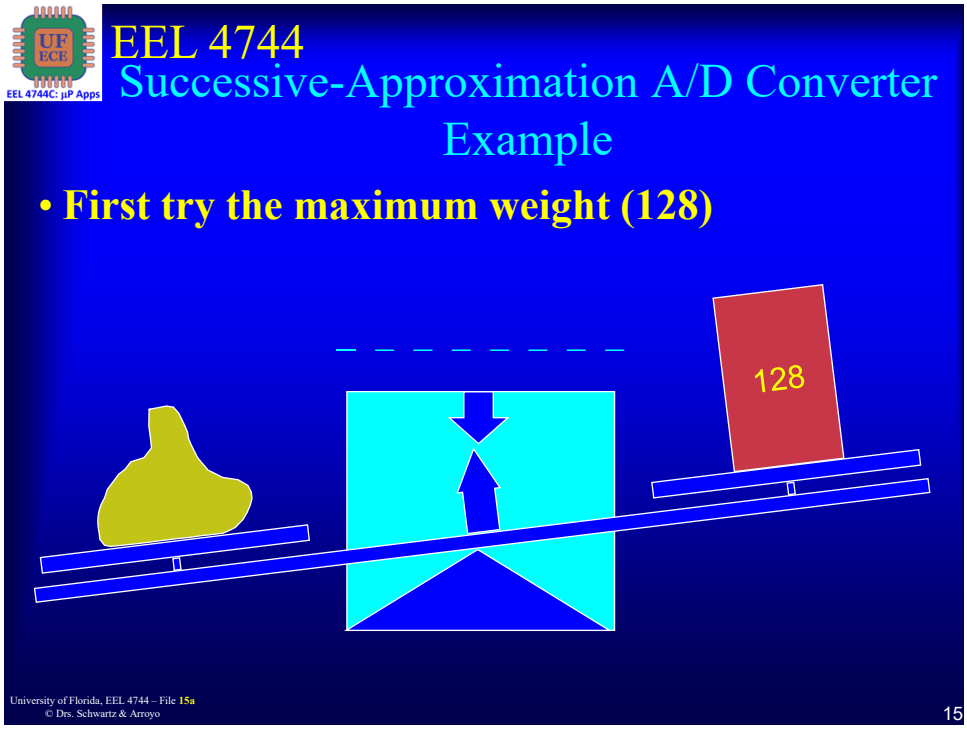
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Successive-Approximation A/D Converter Example
• First try the maximum weight (128)
128
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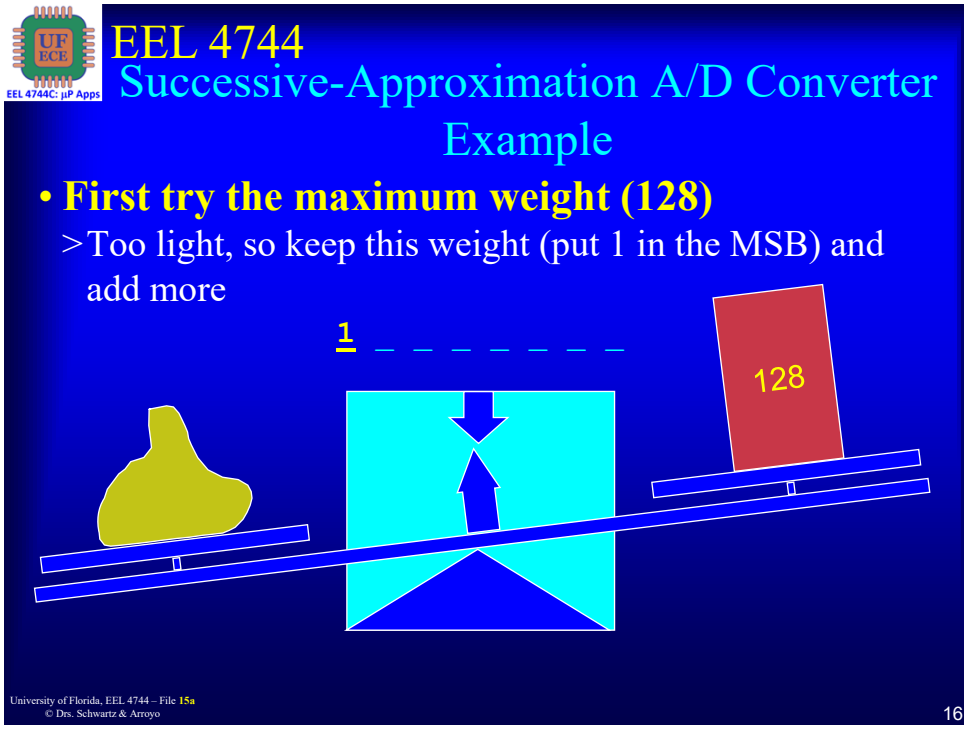
EEL 4744
Successive-Approximation A/D Converter Example
• First try the maximum weight (128)
>Too light, so keep this weight (put 1 in the MSB) and add more
1
128
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16

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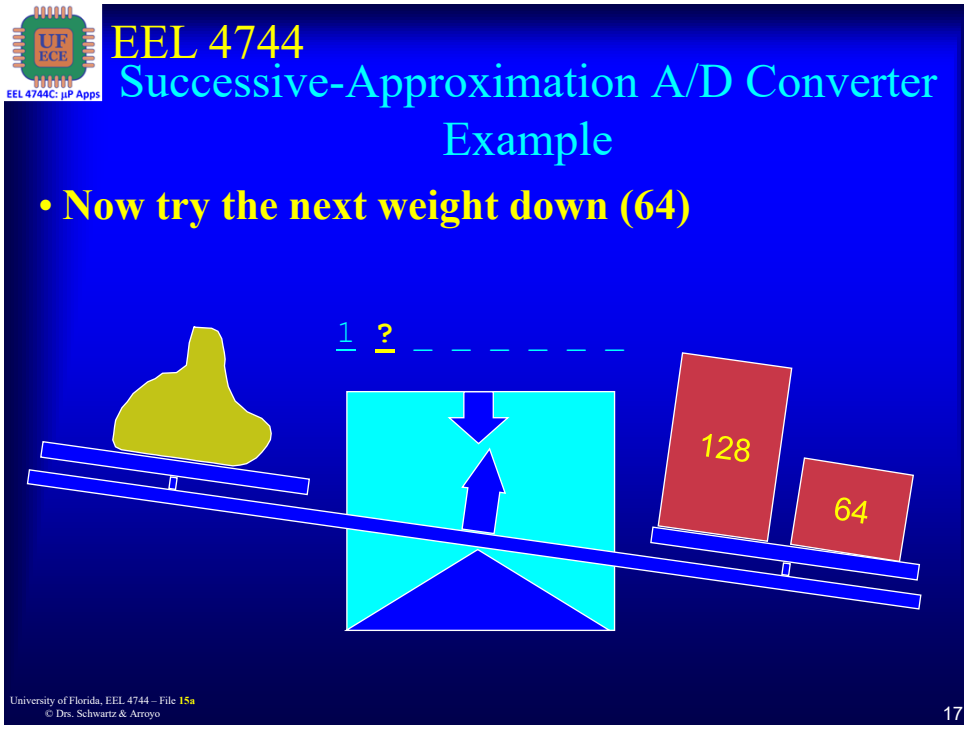
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Successive-Approximation A/D Converter Example
• Now try the next weight down (64)
1 ? _ _ _ _ _ _
128
64
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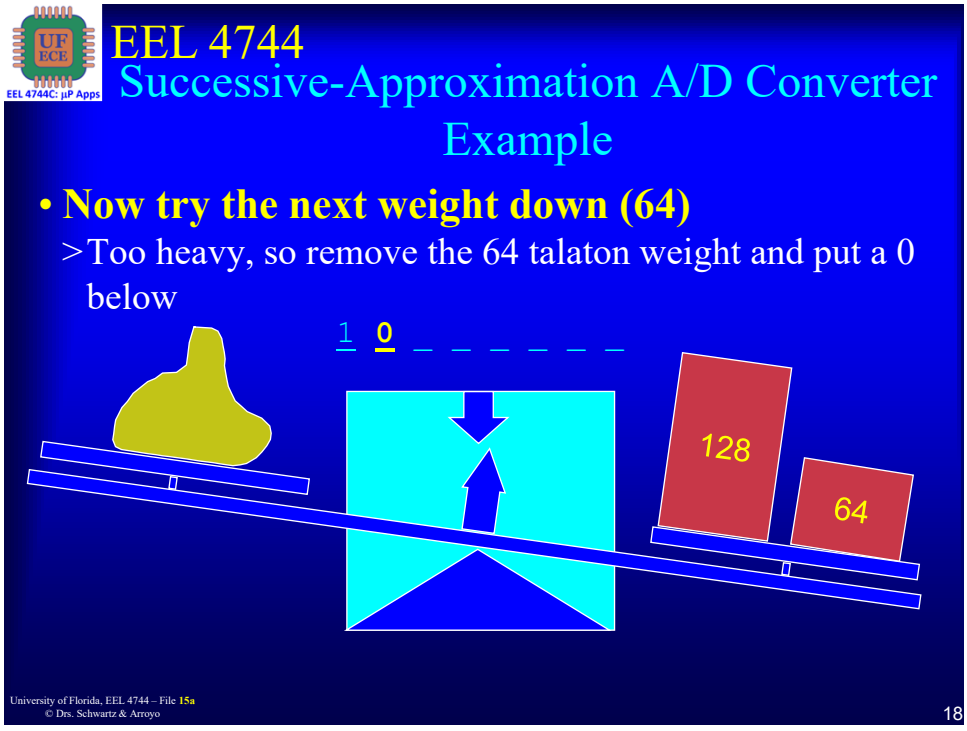
EEL 4744
Successive-Approximation A/D Converter Example
• Now try the next weight down (64)
>Too heavy, so remove the 64 talaton weight and put a 0 below
1 0 _ _ _ _ _ _
128
64
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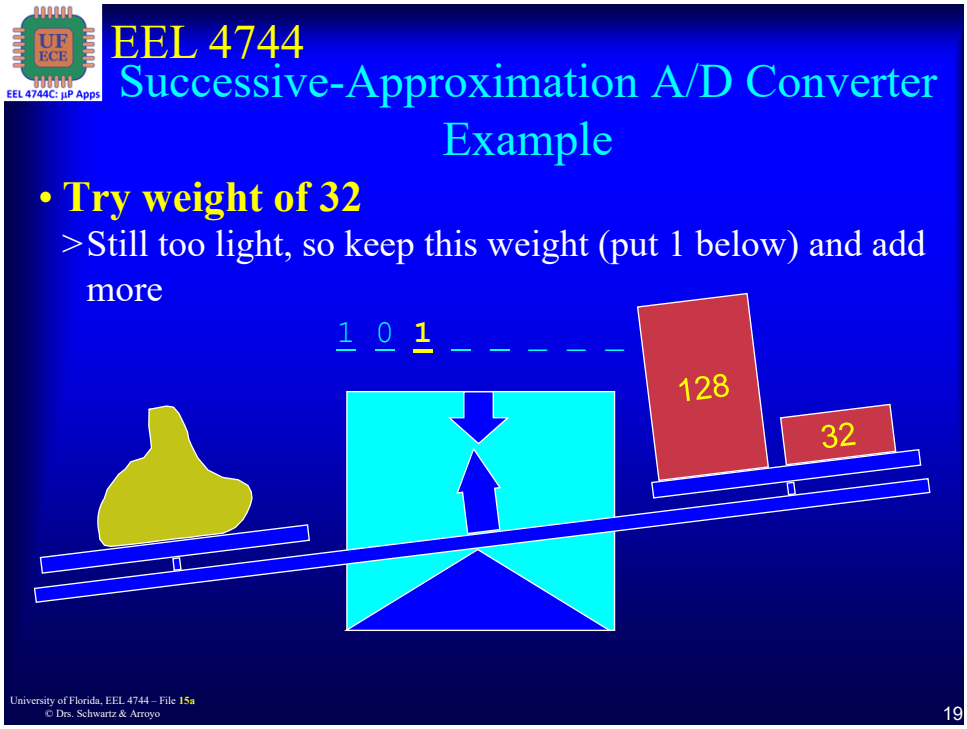
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Successive-Approximation A/D Converter Example
• Try weight of 32
>Still too light, so keep this weight (put 1 below) and add more
1 0 1 _ _ _ _ _
128
32
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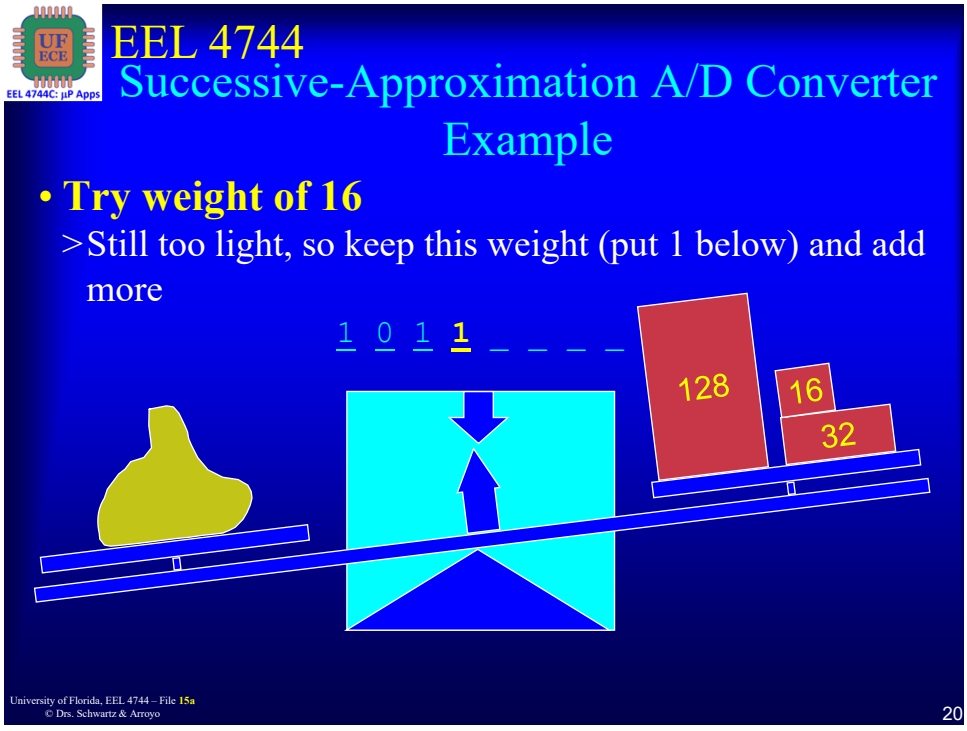
EEL 4744
Successive-Approximation A/D Converter Example
• Try weight of 16
>Still too light, so keep this weight (put 1 below) and add more
1 0 1 1 _ _ _ _
128
16
32
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20

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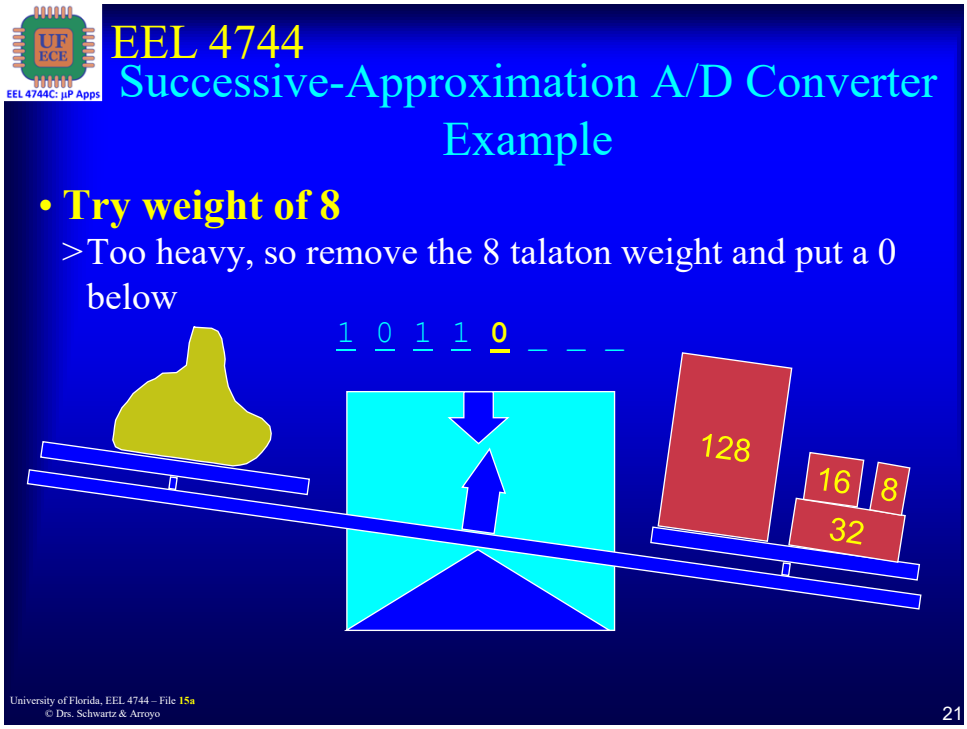
EEL 4744
Successive-Approximation A/D Converter Example
• Try weight of 8
>Too heavy, so remove the 8 talaton weight and put a 0 below
1 0 1 1 0 _ _ _
128
16
8
32
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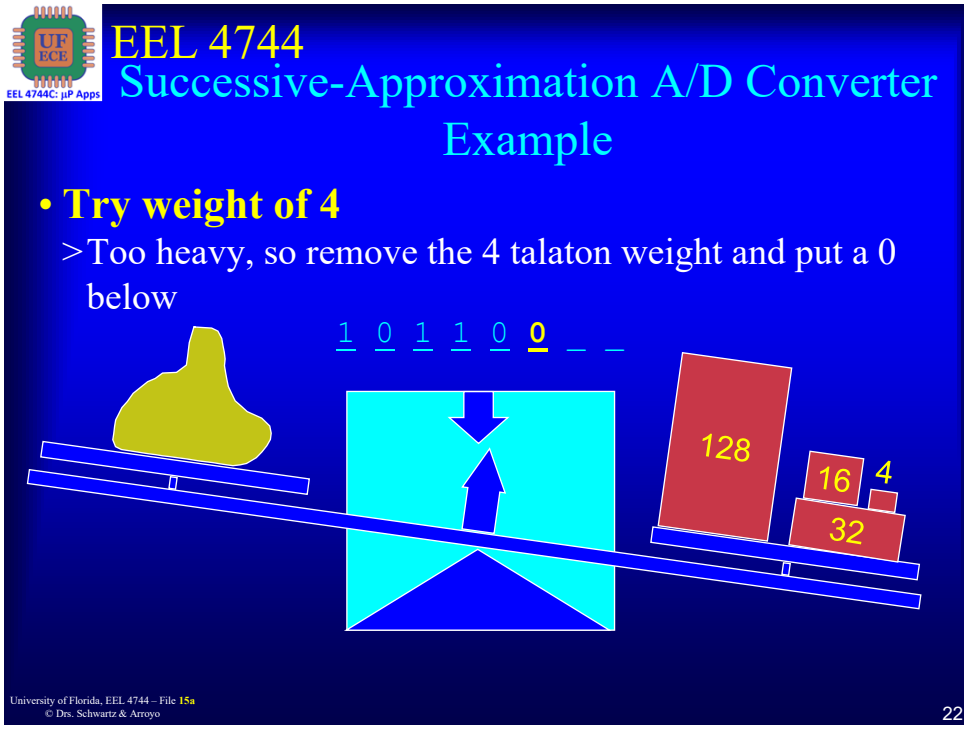
EEL 4744
Successive-Approximation A/D Converter Example
• Try weight of 4
>Too heavy, so remove the 4 talaton weight and put a 0 below
1 0 1 1 0 0 _ _
128
16
4
32
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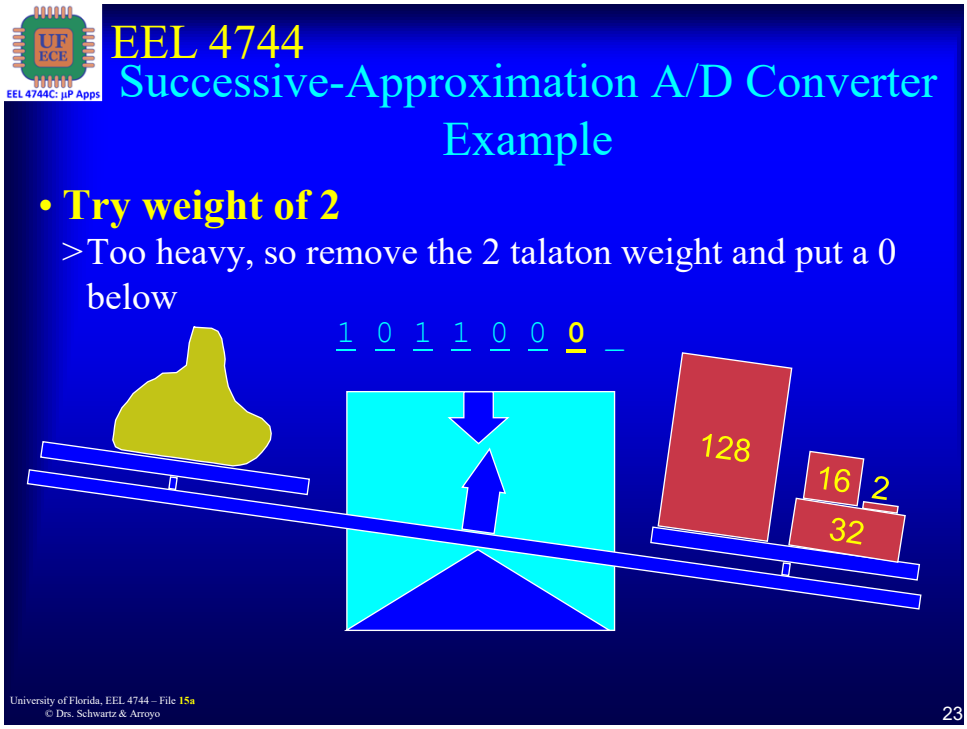
EEL 4744
Successive-Approximation A/D Converter Example
• Try weight of 2
>Too heavy, so remove the 2 talaton weight and put a 0 below
1 0 1 1 0 0 0 _
128
16
2
32
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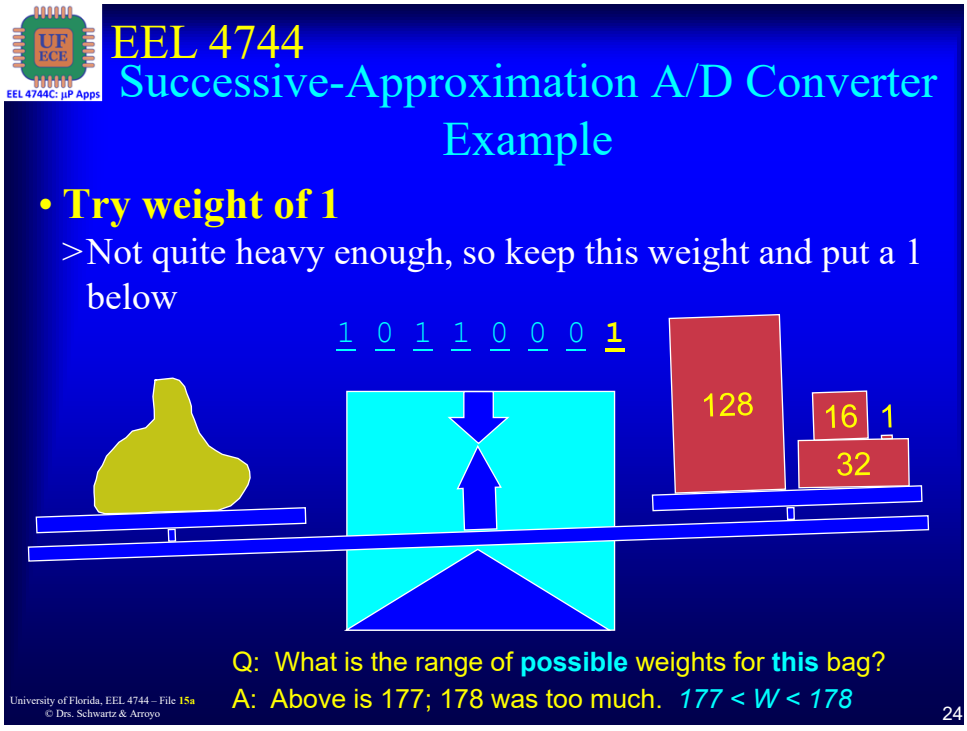
EEL 4744
Successive-Approximation A/D Converter Example
• Try weight of 1
>Not quite heavy enough, so keep this weight and put a 1 below
1 0 1 1 0 0 0 1
128
16
1
32
Q: What is the range of possible weights for this bag?
A: Above is 177; 178 was too much. 177 < W < 178
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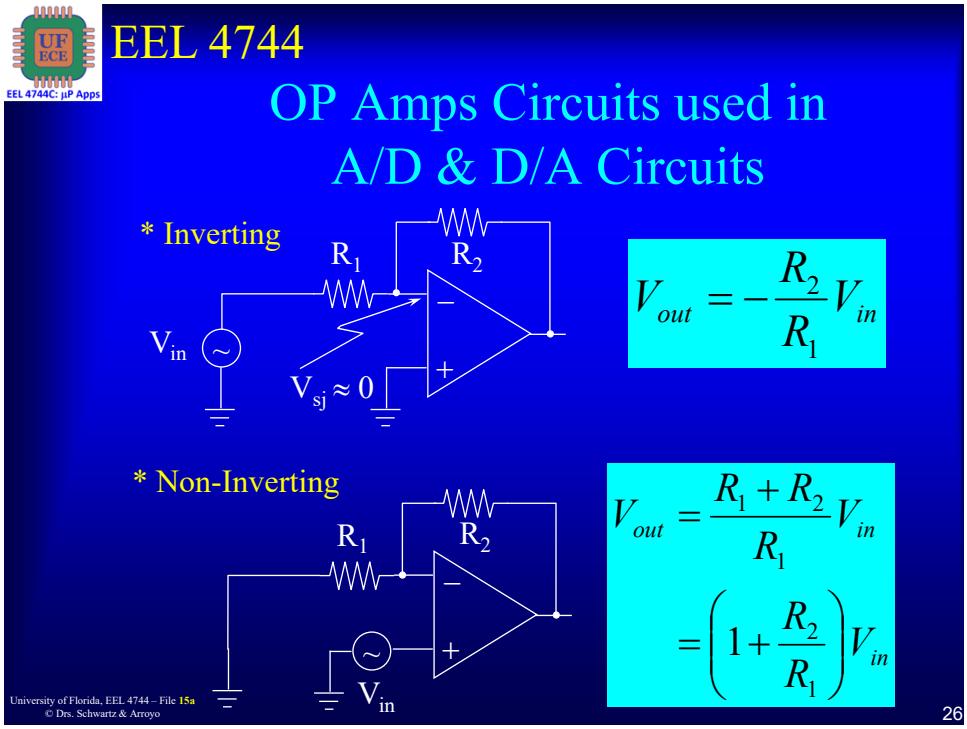
Successive-Approximation A/D Converter
• The above algorithm is called a binary search (since the know weights were 2^n)
• The electronic successive-approximation A/D works with the same principles as the ancient balance, comparing the unknown quantity (voltage) with a succession of know quantities (voltages) with binary weights
• All Successive-Approximation A/D converters have D/A converters (DACs) inside
Bar game; bar puzzle https://youtu.be/S2BB52xc_cc
25

25


EEL 4744
OP Amps Circuits used in A/D & D/A Circuits
* Inverting
R1
R2
Vin
Vsj ≈ 0
Vout = −(R2/R1) Vin
* Non-Inverting
R1
R2
Vin
Vout = ((R1 + R2)/R1) Vin
= (1 + R2/R1) Vin
26

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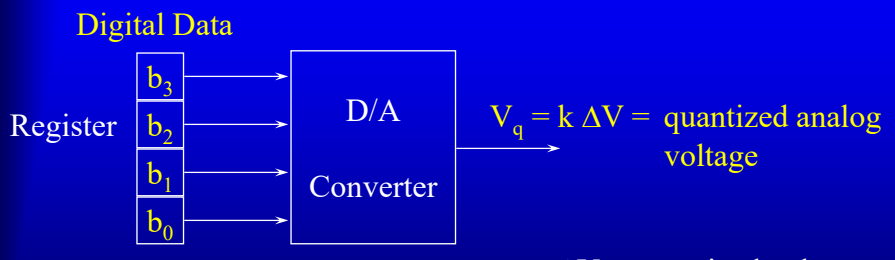
Digital/Analog Conversion

Binary integer: $k = b_3 2^3 + b_2 2^2 + b_1 2^1 + b_0$



ΔV = quantized voltage proportionality constant

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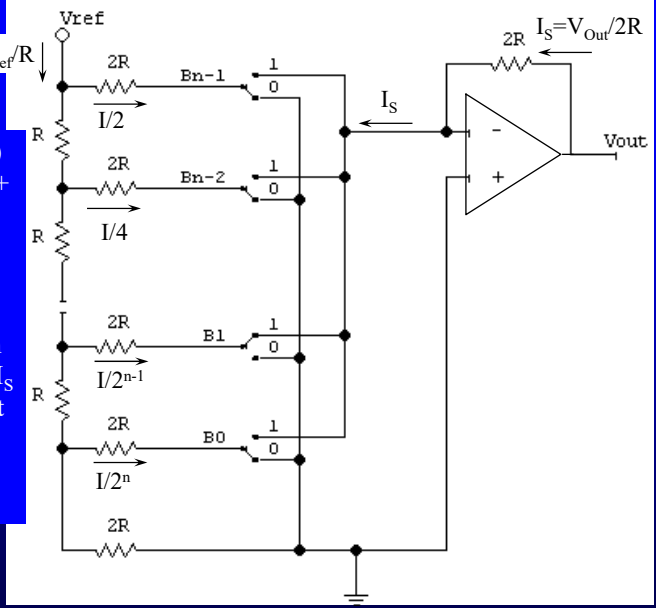
DAC: Inverted R-2R Ladder Circuit

- Ideal Op Amp (see 3111)
  - No current into - & + terminals
  - Voltage at - input is "virtually" equal to voltage at + input
- $V_{Out}=I_S \times 2R$; each branch can add some current to I_S
- Verify that the equivalent resistance of the entire network is R (see next page)



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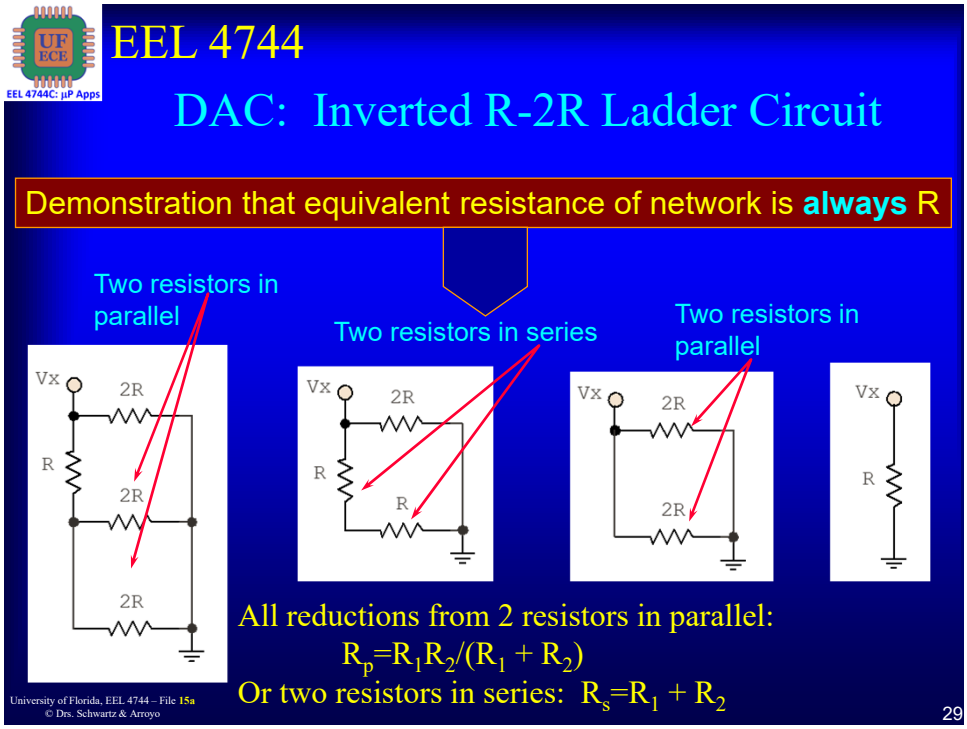
EEL 4744
DAC: Inverted R-2R Ladder Circuit
Demonstration that equivalent resistance of network is always R
Two resistors in parallel
Two resistors in series
Two resistors in parallel
Vx
2R
R
All reductions from 2 resistors in parallel:
$R_p=R_1R_2/(R_1+R_2)$
Or two resistors in series: $R_s=R_1+R_2$
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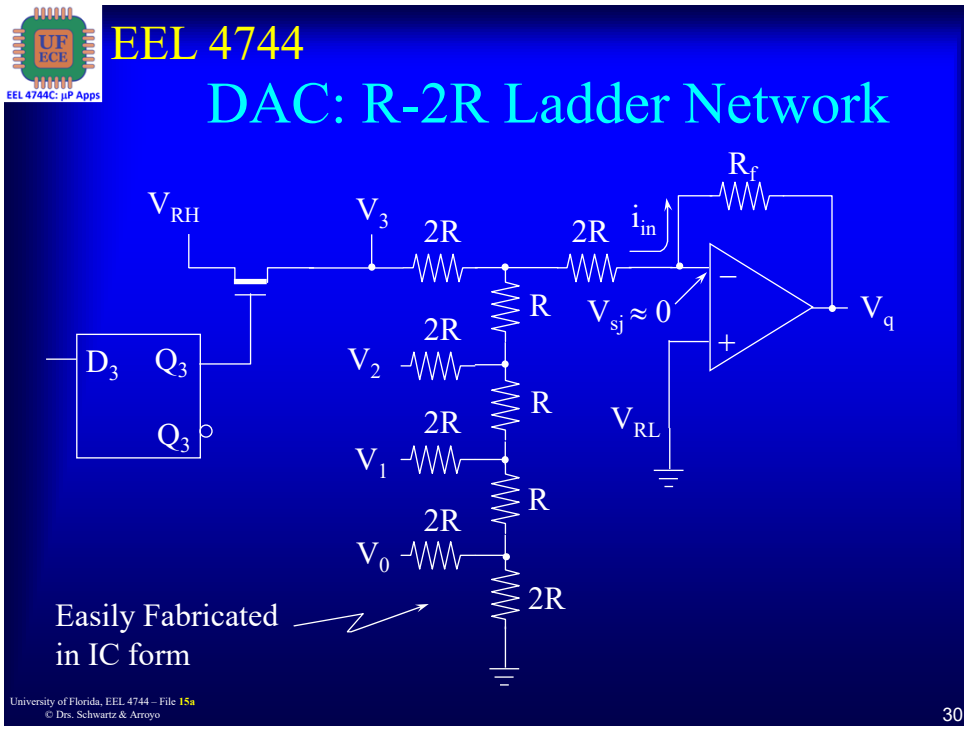
EEL 4744
DAC: R-2R Ladder Network
V_{RH}
V_3
V_2
V_1
V_0
2R
R
R_f
i_{in}
$V_{sj} \approx 0$
V_q
V_{RL}
D_3
Q_3
$\overline{Q_3}$
Easily Fabricated in IC form
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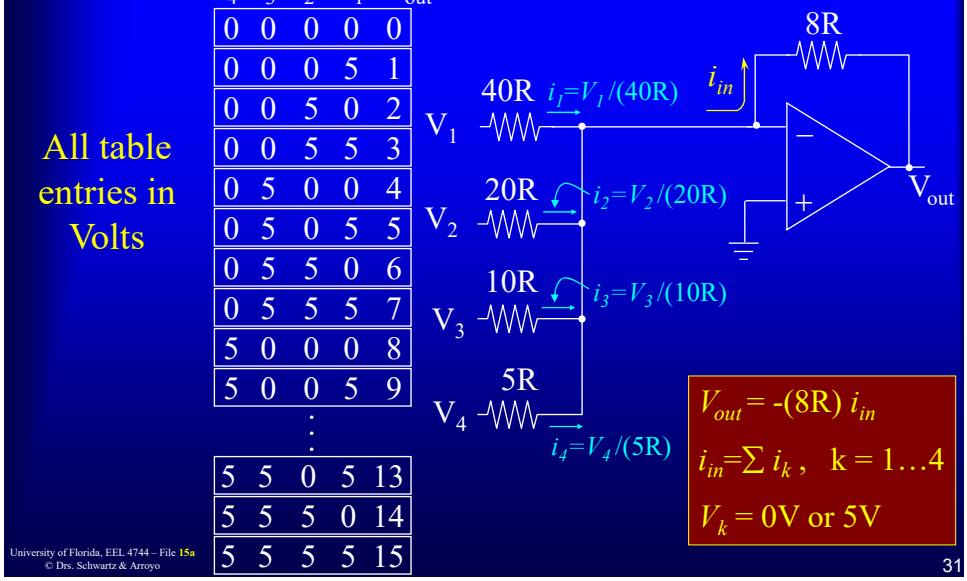
Another 4-Bit DAC

All table entries in Volts

V_4	V_3	V_2	V_1	$-V_{out}$
0	0	0	0	0
0	0	0	5	1
0	0	5	0	2
0	0	5	5	3
0	5	0	0	4
0	5	0	5	5
0	5	5	0	6
0	5	5	5	7
5	0	0	0	8
5	0	0	5	9
:				
5	5	0	5	13
5	5	5	0	14
5	5	5	5	15



$V_{out} = -(8R)\, i_{in}$

$i_{in} = \sum i_k$, k = 1…4

V_k = 0V or 5V

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EEL 4744

Analog/Digital Conversion

- A/D Conversion Methods
  - >Successive Approximation
  - >Flash Conversion

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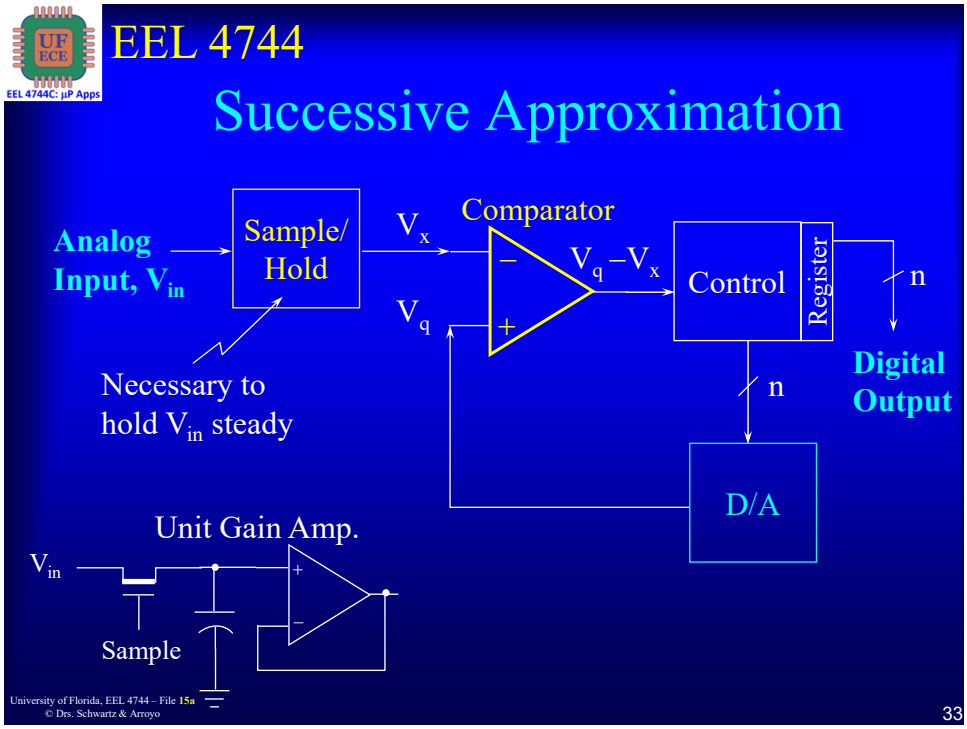
EEL 4744
Successive Approximation
Analog Input, V_{in}
Sample/ Hold
V_x
V_q
Comparator
$V_q - V_x$
Control
Register
n
Digital Output
n
D/A
Necessary to hold V_{in} steady
Unit Gain Amp.
V_{in}
Sample
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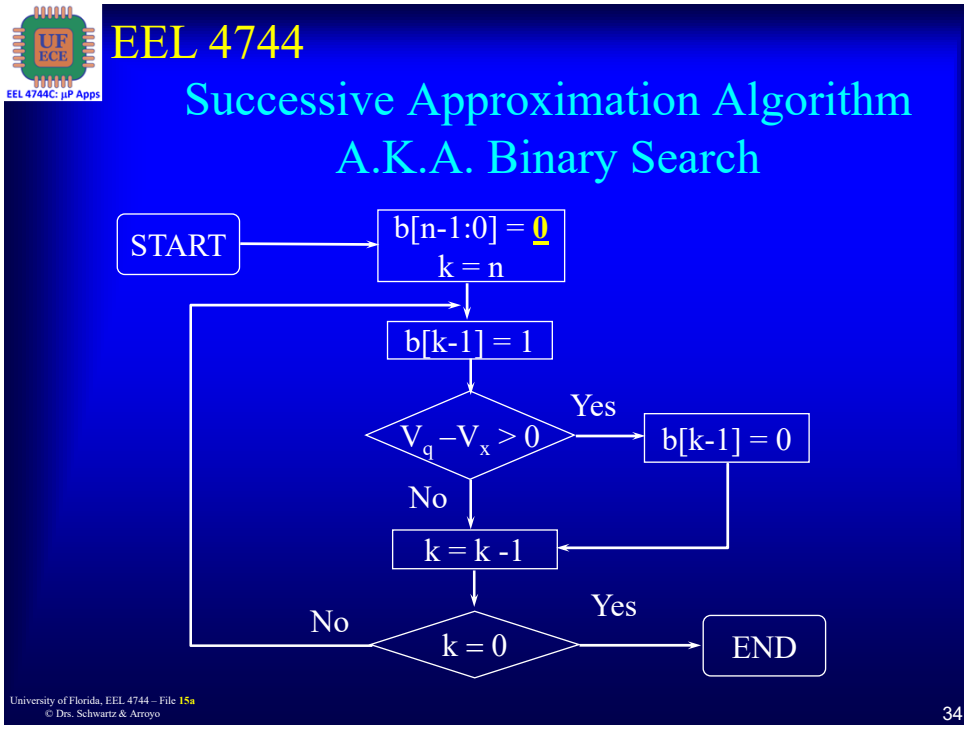
EEL 4744
Successive Approximation Algorithm
A.K.A. Binary Search
START
b[n-1:0] = 0
k = n
b[k-1] = 1
$V_q - V_x > 0$
Yes
b[k-1] = 0
No
k = k -1
k = 0
No
Yes
END
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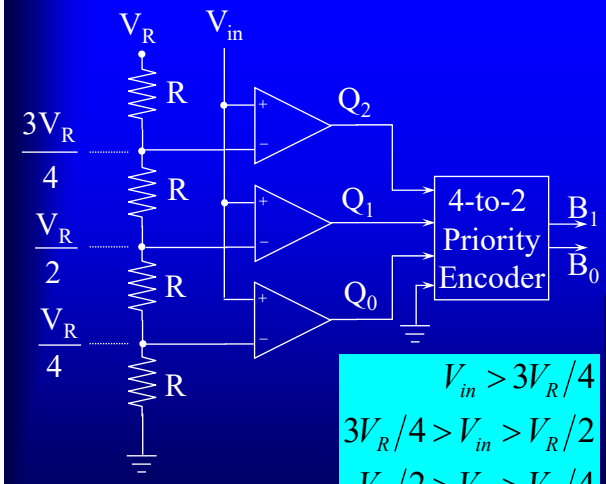
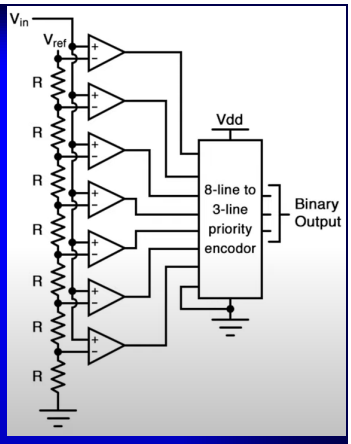
Flash Conversion





$V_{in} > 3V_R/4$

$3V_R/4 > V_{in} > V_R/2$

$V_R/2 > V_{in} > V_R/4$

$V_R/4 > V_{in} > 0$

Q_2	Q_1	Q_0	B_1	B_0
1	1	1	1	1
0	1	1	1	0
0	0	1	0	1
0	0	0	0	0

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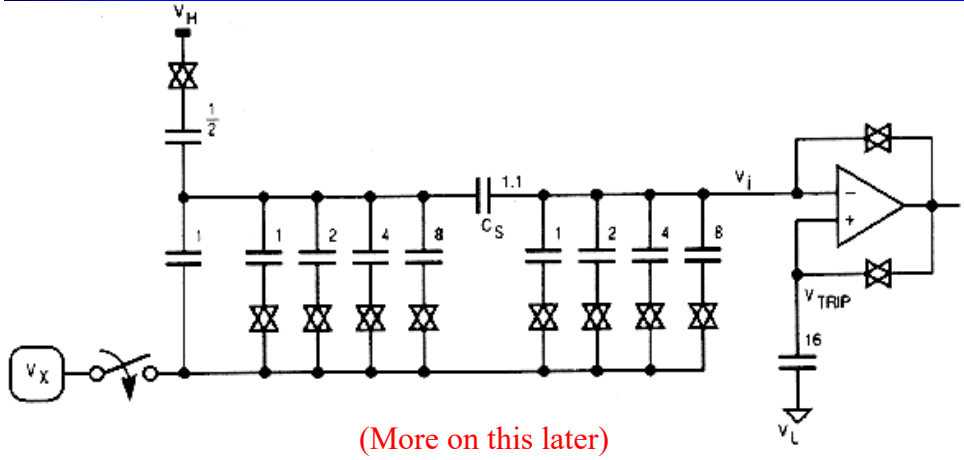
A/D Successive-Approximation Control



(More on this later)

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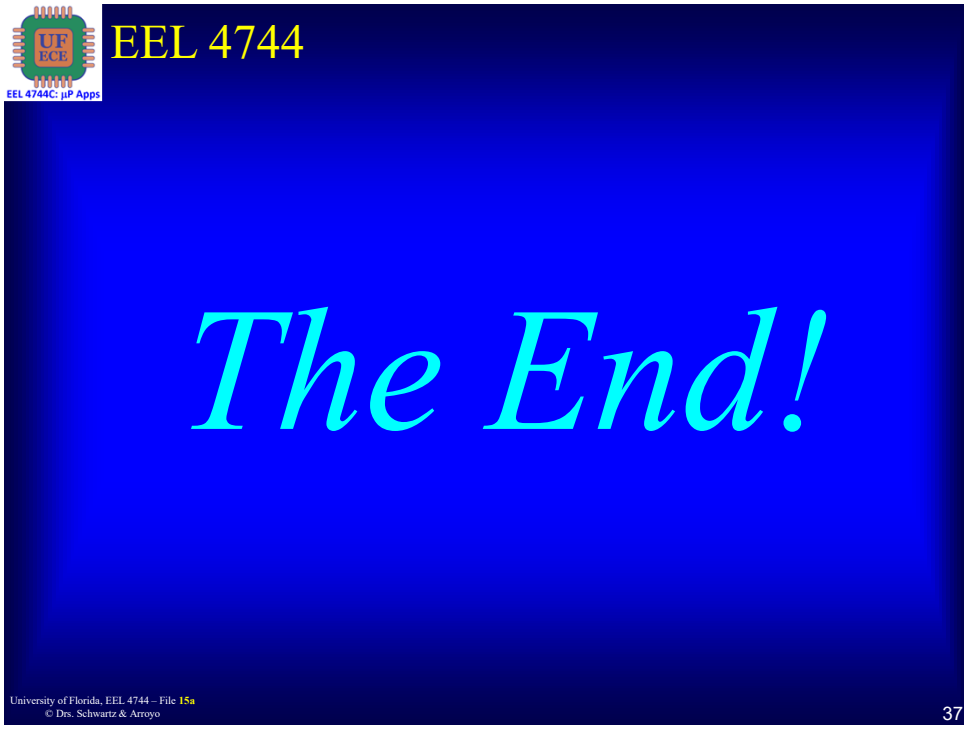
EEL 4744
EEL 4744C: µP Apps
The End!
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