University of Glasgow

Electronic System Design UESTC3003

Lecture 1: Introduction, Course Overview, Electronic Systems

Dr Sajjad Hussain
Thanks to Prof. Duncan Bremner

WORLD CHANGING GLASGOW

Sajjad.Hussain.2@glasgow.ac.uk

Teaching Team

Dr Anthony Centeno (Course coordinator)
(Anthony.Centeno@glasgow.ac.uk)

Dr Sajjad Hussain
(sajjad.Hussain.2@glasgow.ac.uk)

The teaching team are here to help and can be contacted via email.
We aim to reply to your emails within 2 working days.

…the Design Wizard conversion course

Also known as:-

- What is System Design?
- You will learn real circuit and system design tricks
- You will learn when a design is 'good enough'
- You will learn how to read datasheets
- You will learn how to deal with small signals
- You will learn the importance of good design

University of Glasgow

Course Outline

ESD consists of 4 main topics:

- What is System Design and how to do it properly
- System Design with Static Errors
- System Design with Dynamic Errors
- Noise and low noise design

Course does not cover some **important** things:
Statistical design methods; High frequency / dynamics;
Passive component characteristics; Drift of errors; Micropower / Single supply design…

Course Documentation and Texts

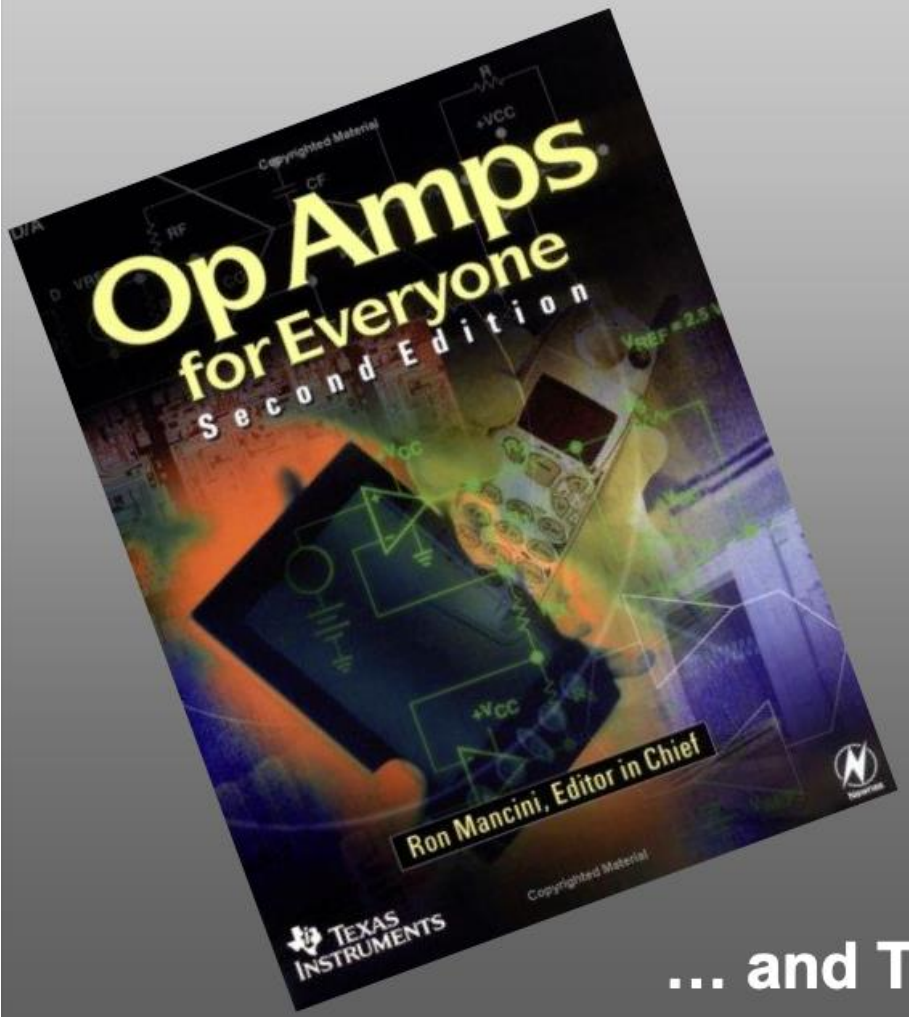
- Course is based on course developed in Glasgow by Prof Jon Weaver and Prof Duncan Bremner
- Modified & improved to meet the needs of UESTC Joint School
- Most material will be available on Moodle (Lecture Notes, Labs, datasheets etc.)
  - *You need to **attend** class to understand the notes!!*

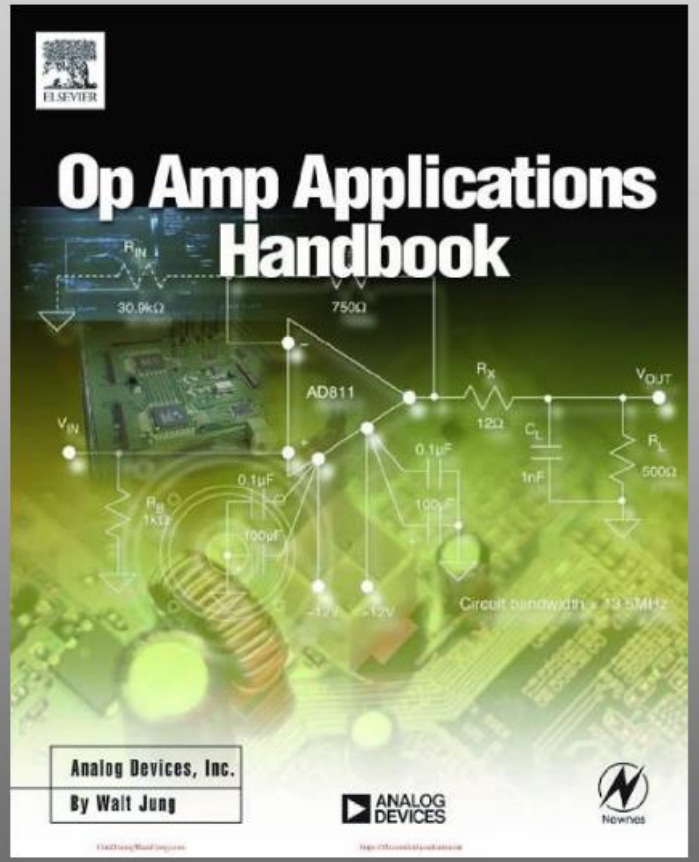
Textbooks:

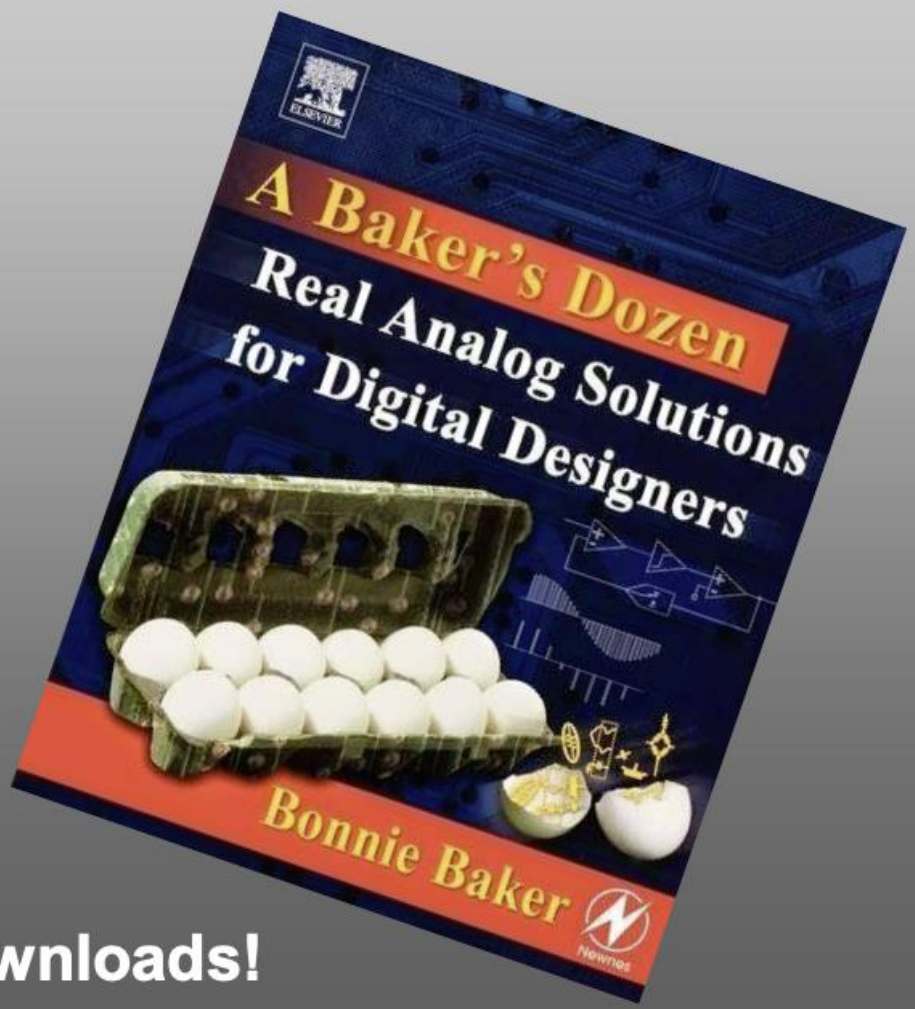
- Microelectronic Circuits (7th Edition); Sedra, A and Smith, K; Oxford University Press, 2016
- Opamps for Everyone R. Mancini
- Op Amp Applications Handbook (Analog devices pub. Walt Jung Ed.) FREE Download http://www.analog.com/en/education/education-library/op-amp-applications-handbook.html
- A Baker's Dozen: Real Analog Circuits for Digital Engineers; (Newnes) B. Baker ISBN: 978-0-7506-7819-3

University of Glasgow

Reference books to keep throughout your career…







… and TWO of them are free downloads!

ESD Assessment

- **There will be 2 summative assessments:**

1. Design Exercise Report. A formal report will need to be submitted at the end of week 14. It will be worth 25% of the total mark.

2. Final Examination. There will be an end of course final examination worth 75% of the total mark.

Course Delivery Format

- This course will be delivered via 12 face-to-face lectures over the first semester of AY2023-24
- Each Lecture is ~90 minutes and will consist of lecturing, video tutorials, in-class exercises, and worked examples
- Labs will be run using lab sheets and with the help of GTAs. Labs are unseen problems and should not be attempted beforehand.

University of Glasgow

Course Schedule

Week	Lecture	UoG Teaching Staff	Lab
3	Welcome and Introduction to Electronic System Design (Introductory Video on Moodle)	Dr Anthony Centeno	
	Operational Amplifiers (OpAmp)	Dr Sajjad Hussain	
	OpAmp Imperfections	Dr Sajjad Hussain	Lab 1
7	OpAmp Imperfections - Static Errors	Dr Sajjad Hussain	
	Figure of Merits	Dr Sajjad Hussain	Lab 2
	Grounding and CMRR	Dr Sajjad Hussain	
11	The Instrumentation Amplifier	Dr Anthony Centeno	
	The Instrumentation Amplifier Applications	Dr Anthony Centeno	
	Design Challenge 2023 Introduction to Noise	Dr Anthony Centeno	Lab 3
	Noise Calculations	Dr Anthony Centeno	
15	Low Noise Design and Analysis	Dr Anthony Centeno	MCQ Revision
	Revision Lectures	Dr Anthony Centeno/Dr Sajjad Hussain	

University of Glasgow

Let’s get into it!

University of Glasgow

First Question: What is a System?

A System: A set of things working together as parts of a mechanism or an interconnecting network; a complex whole [to implement a defined function]

Physiology: A set of organs in the body with a common structure or function.
'the digestive system'

Computing /Electronics: A group of related hardware units or programs or both, especially when dedicated to a single application.

System Design: The process of defining elements of a system like modules, architecture, components and their interfaces and data to realise a function based on the specified requirements.

It is the process of defining, developing, and designing systems which satisfies the specific requirements of a customer or user.

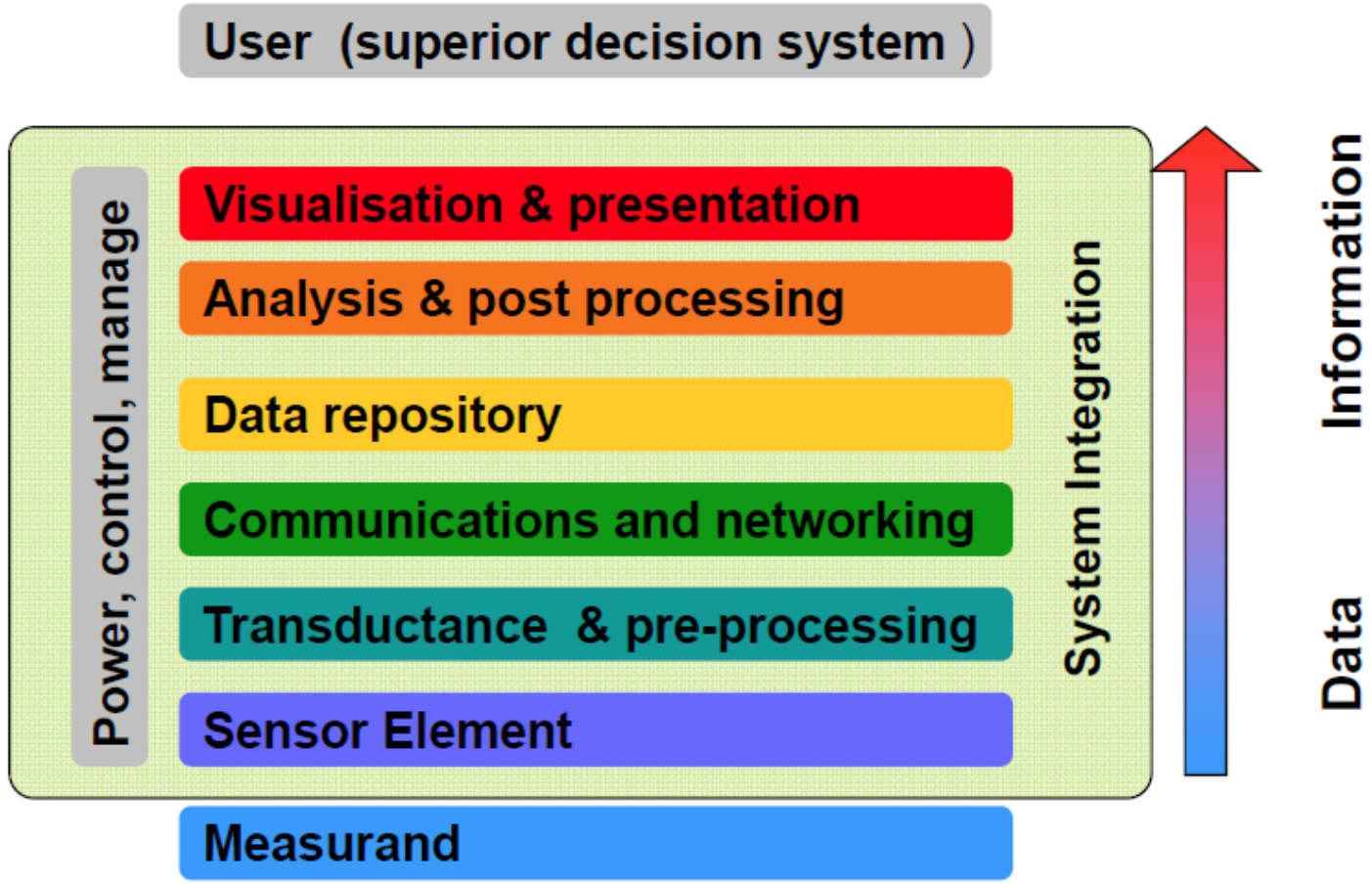
University of Glasgow

All Systems consist of:-

Commodity	Perform Function	System
Passengers	Rail/Air	Transport
Electricity	Power Grid	Energy Distribution
Money	Banks	Business Growth
Temperature	Controller	Food Freezer
Voltage	Gain = X21.73	Amplifier
Internet Traffic	Measure ‘hits’	Traffic Control

University of Glasgow

Sensors System Stack



A single hierarchical model defines clear interfaces across the system

Read Full paper at: http://eprints.gla.ac.uk/104909/1/104909.pdf

University of Glasgow

What is "System Design"?

ESD is all about Choice and making engineering decisions:-

Which car is “better”?

Fuel Economy

Price

Luggage space

Passengers

Quick

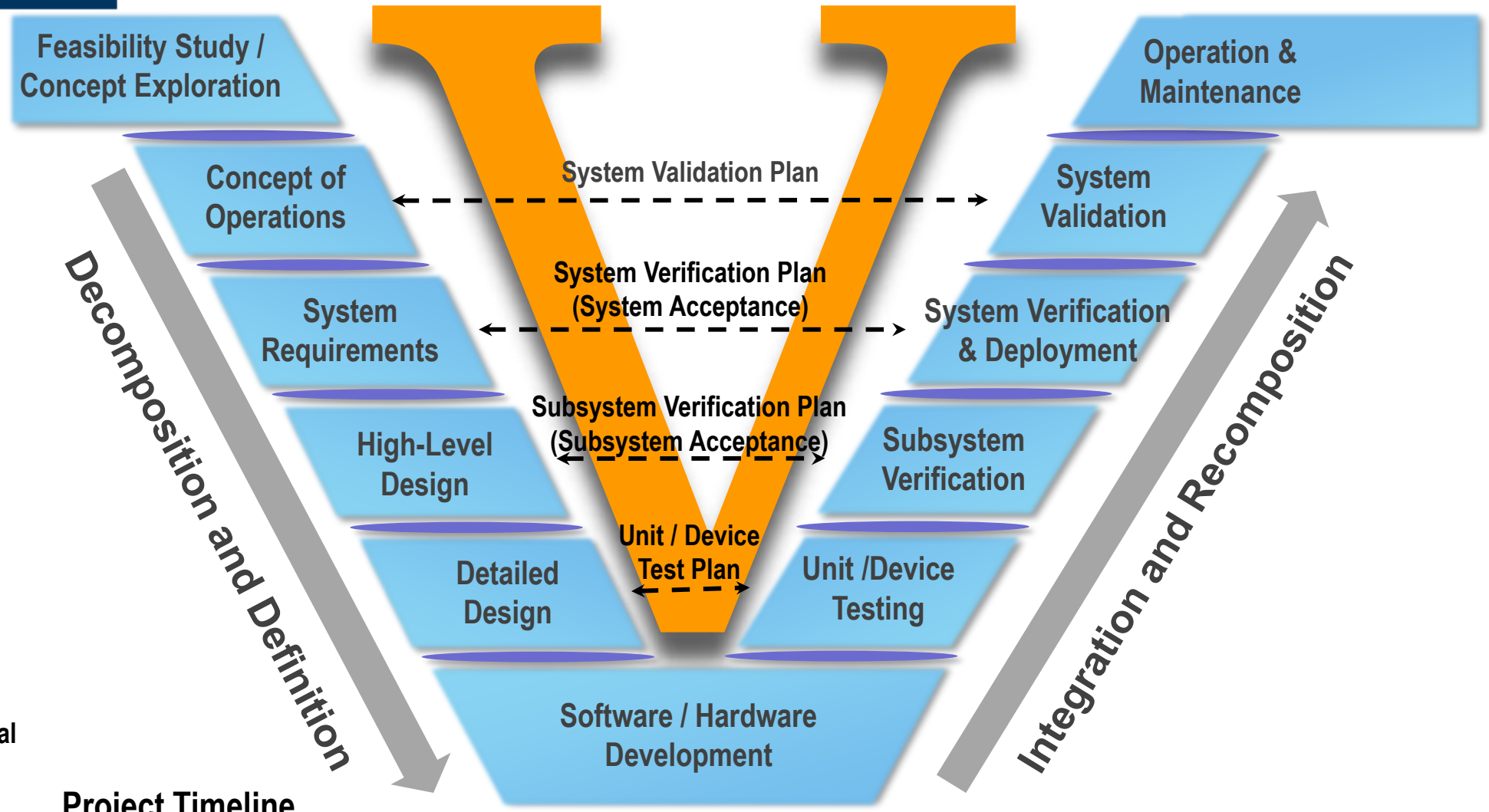
Both are good

You need to understand what THE CUSTOMER or USER wants!!

You need to understand what THE CUSTOMER /USER wants!!

University of Glasgow

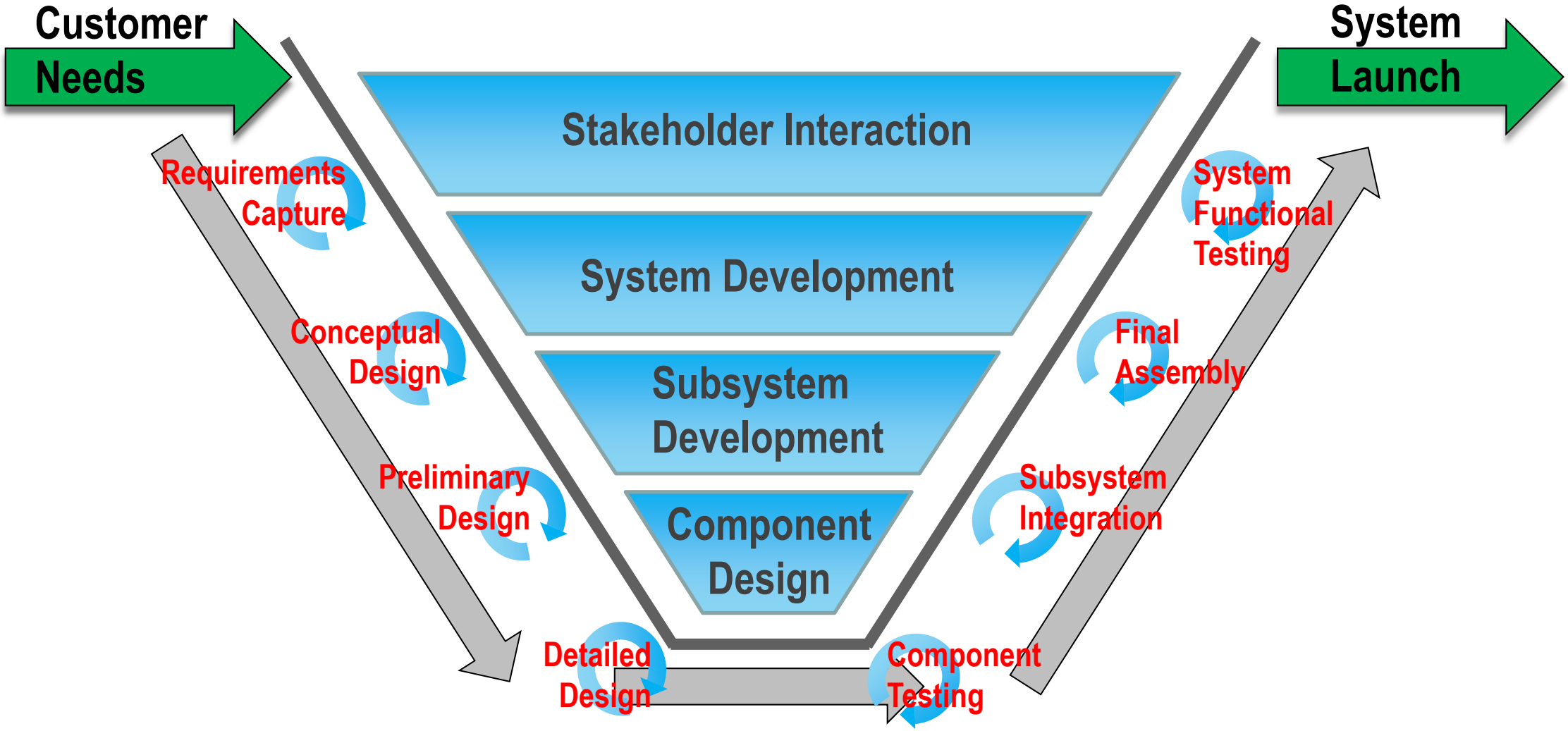
System Design is Hierarchical: The 'V' Model



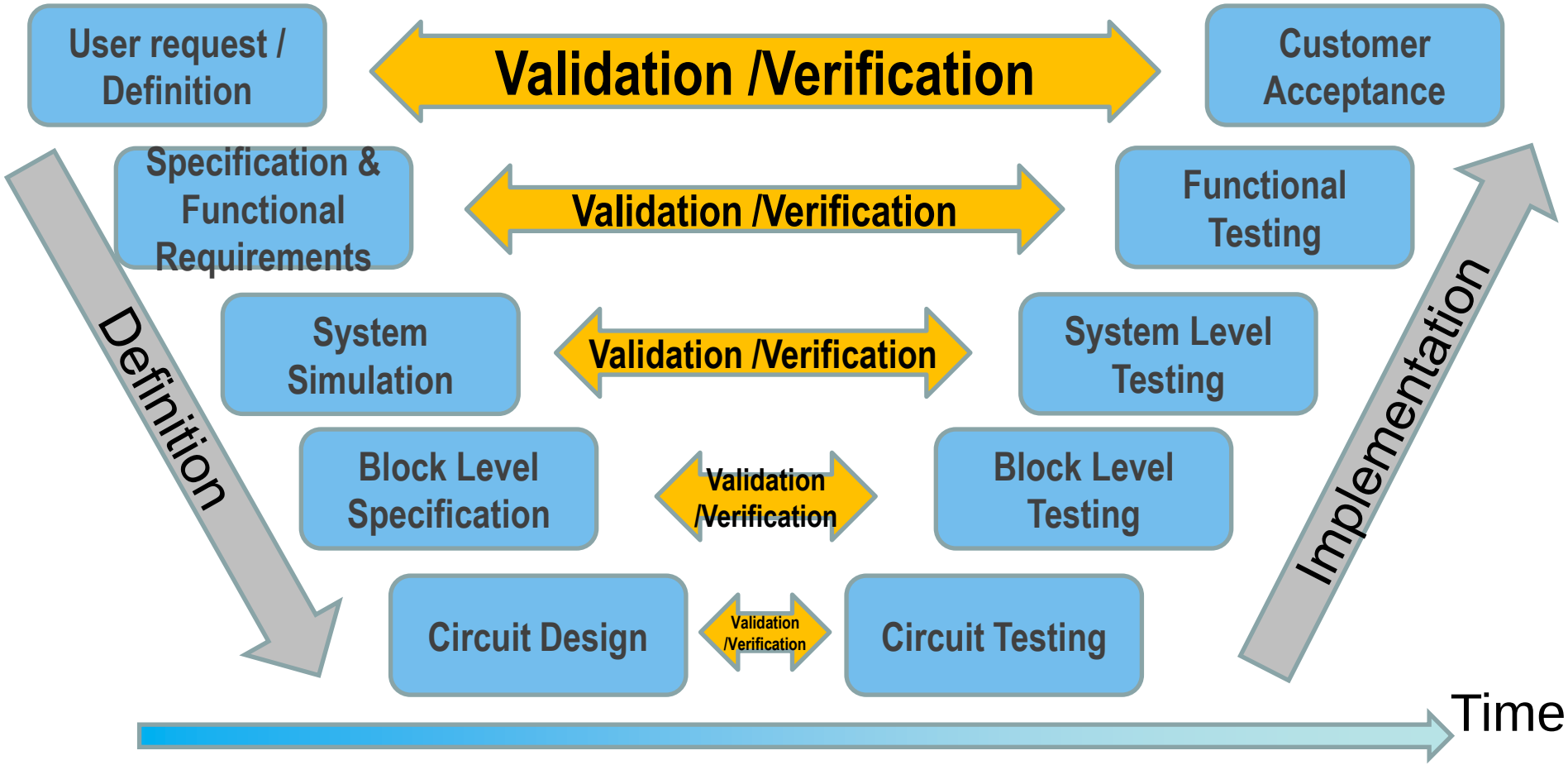
Source:
US Federal Highways Agency

University of Glasgow

Electronic Systems Engineering Overview



Key steps in ESD



Validation: Are you doing the right thing (meeting customer requirements)?

Verification: Are you meeting the specifications (for a given function)?

University of Glasgow

Summary of System Engineering

- System design starts and ends with the customer…
  - You must understand the application and the use case of the system
- It is a hierarchical process and every stage relies on the previous stage
  - You must take care throughout the process
- Validation (doing the right thing), and Verification (does it meet spec) are critical at all stages
  - When you are on the left side of the ‘V’ (Decomposition and Definition), you must be thinking how you will test and deliver the final system on the right side of the ‘V’ (Integration and Recomposition)
- Hardware design /Software design depend on good specifications

University of Glasgow

Electronic System Design

Examples of System Design:
System or Component??

WORLD CHANGING GLASGOW

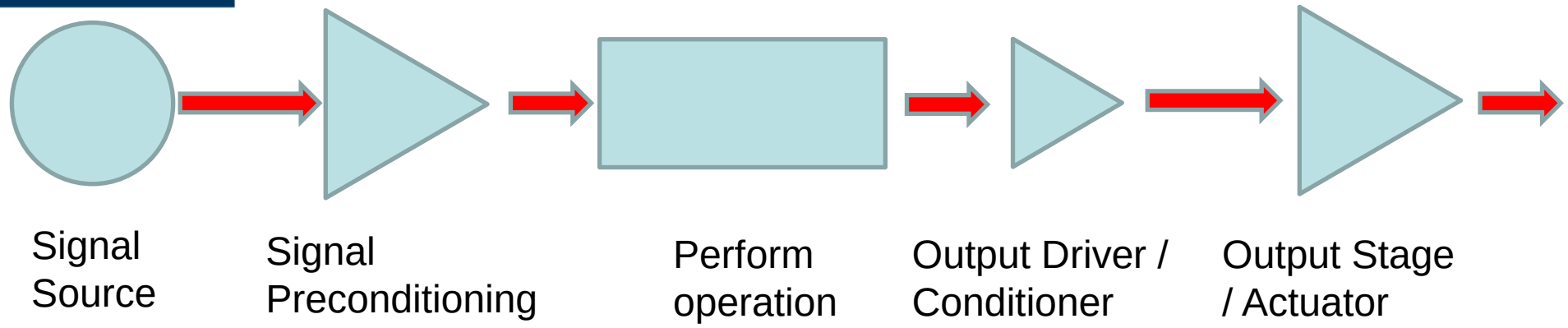
The secret to good system design

1. **Understand the application**
   - WHAT is the customer /user trying to do?
   - WHERE is the customer /user trying to do it?
   - WHAT accuracy/precision /units is required (10s,1V, 10uA, 10ps…)
2. **Take a holistic (wide) view of the problem**
   - Do not ‘rush’ to a solution; spend time UNDERSTANDING
   - Try to consider several different approaches to the problem
3. **Approach the problem systematically**
   - Use the ‘V’ Model
   - Document your decisions: If you discover you were ‘wrong’ you can change the decision and try again.
   - Always consider HOW you will **VALIDATE** and **VERIFY** the results

How to assemble the parts…

We can all access the same parts… the difference is how we use the parts to meet the customer need.

In ESD, interfaces are key…

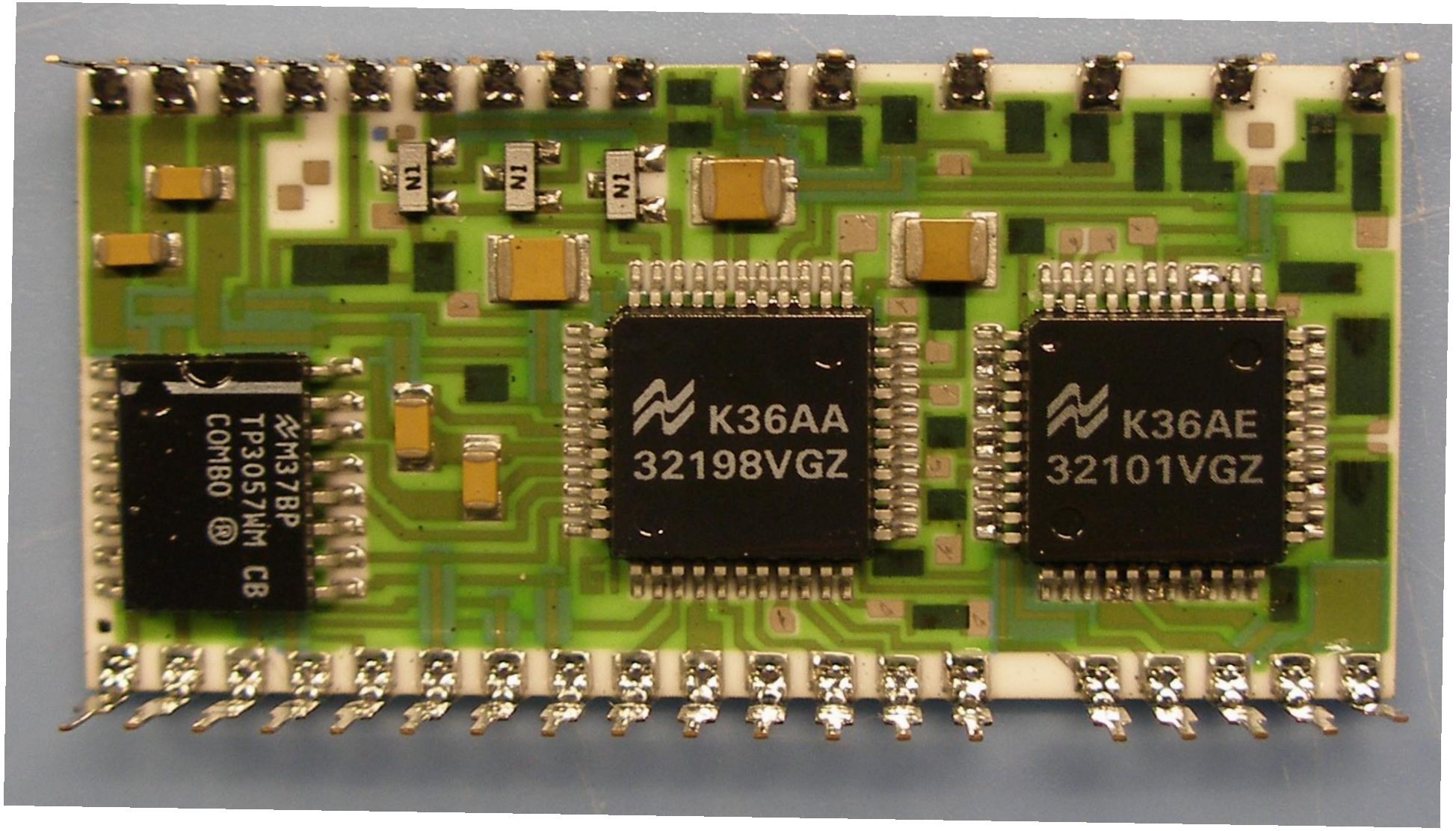


1. Signal Source: Could generate voltage, current, charge, resistance (change of)…
   - Question: what Specification describes the input signal?
2. Signal Preconditioning: Amplifying, Filtering (shaping), frequency shifting, limiting…
   - Question: what Specification of output is needed?
3. Perform Operation: Could be analog or digital:
   - Question: what Specification / accuracy / precision is needed?
4. Output Driver / Conditioner: What is it driving? Specification?
5. Output Stage: What is the interface for output (current drive, voltage drive, fast, slow…) Specification

A good systems engineer knows their interfaces… as well as internal block functions!!

University of Glasgow

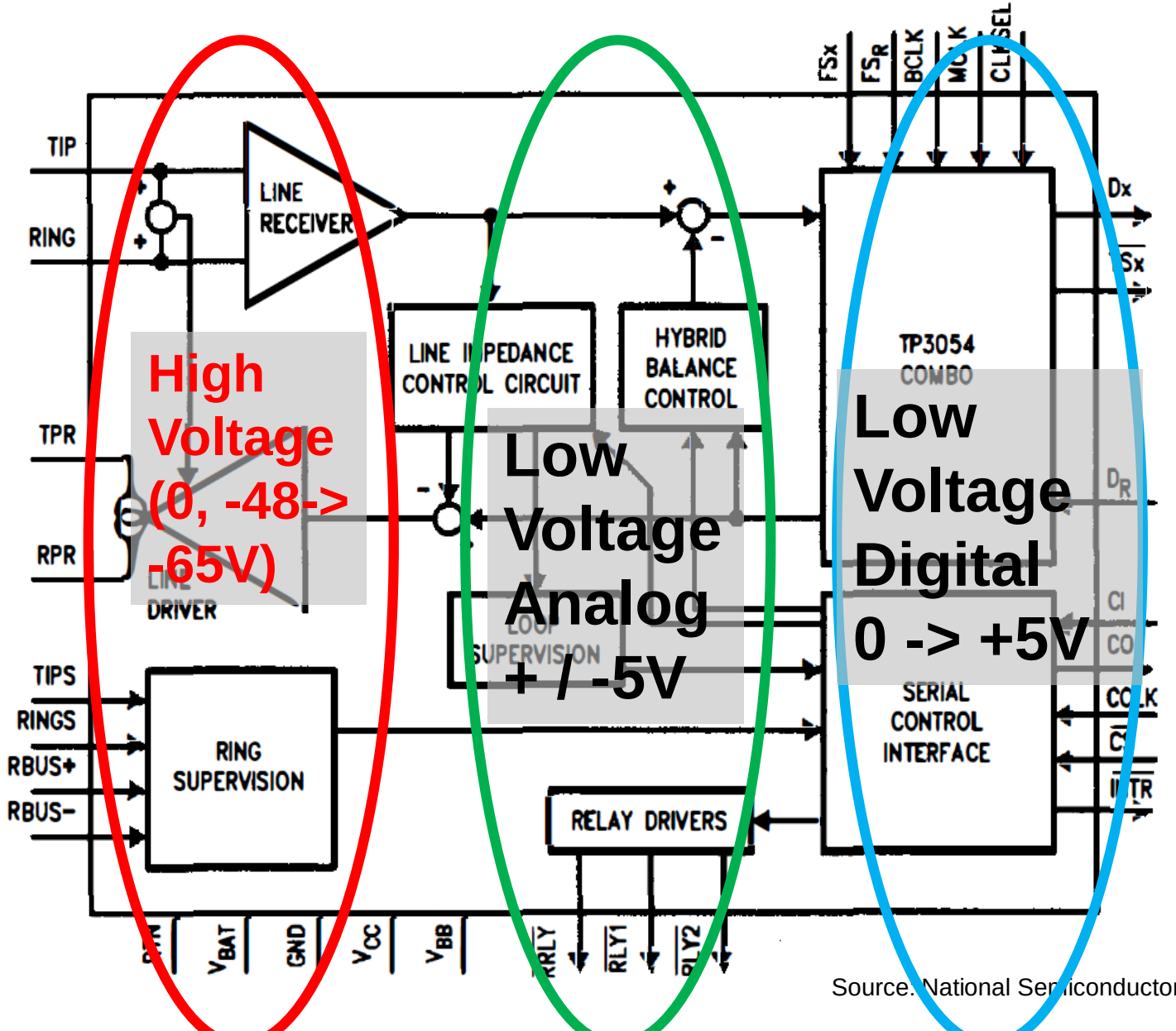
Typical Electronic System (Analog)



Simplified System Block Diagram

TP3210 (SLIM)

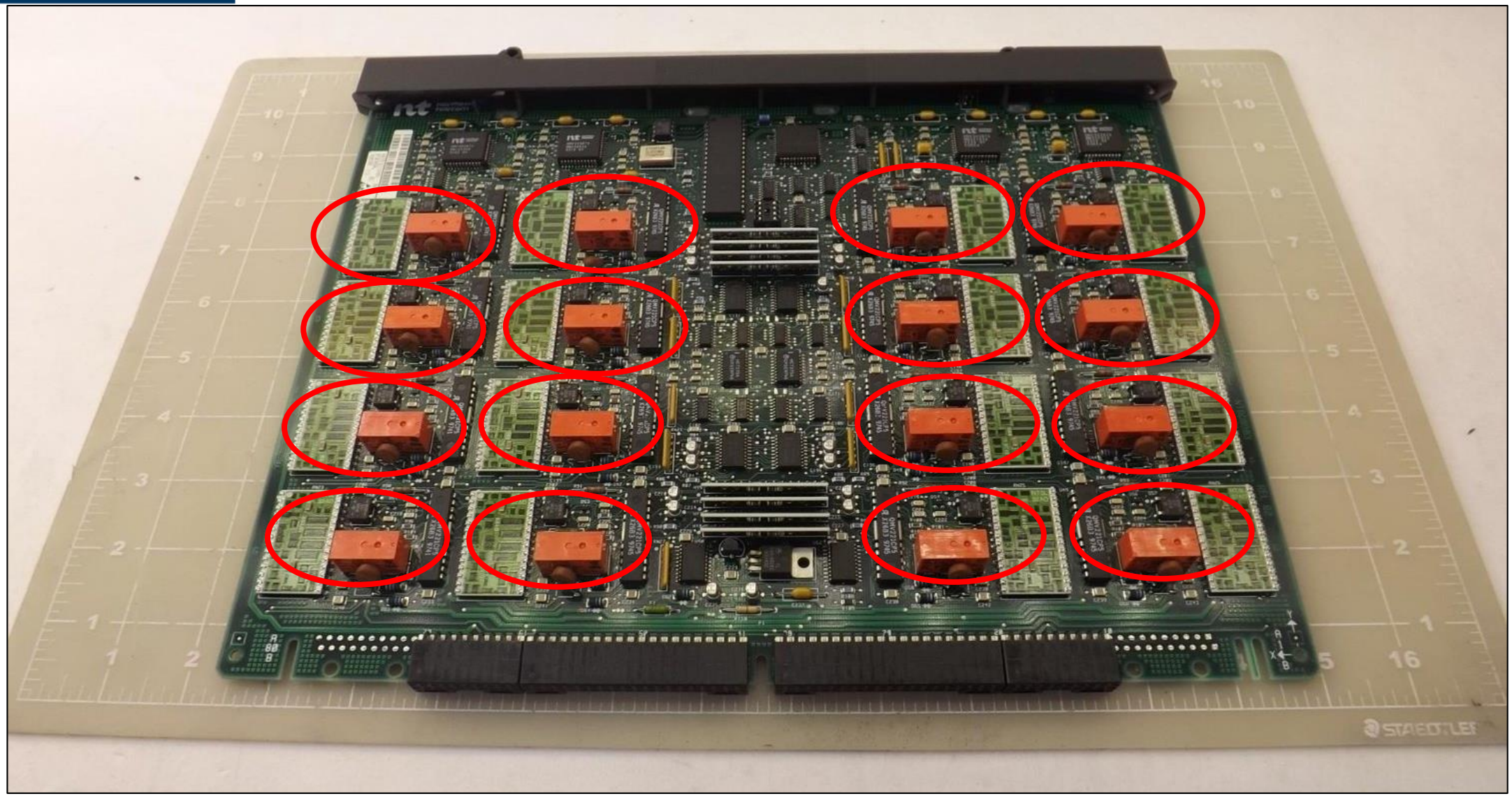
- Telecoms Subscriber Line Interface Circuit (SLIC)
- Millions sold in China in 1990s to connect analog telephones to network (before mobile)
- Every city had a Central Office that connected to up to 3Million telephones



Source: National Semiconductor TP3210 Datasheet

University of Glasgow

A board containing many ‘systems’



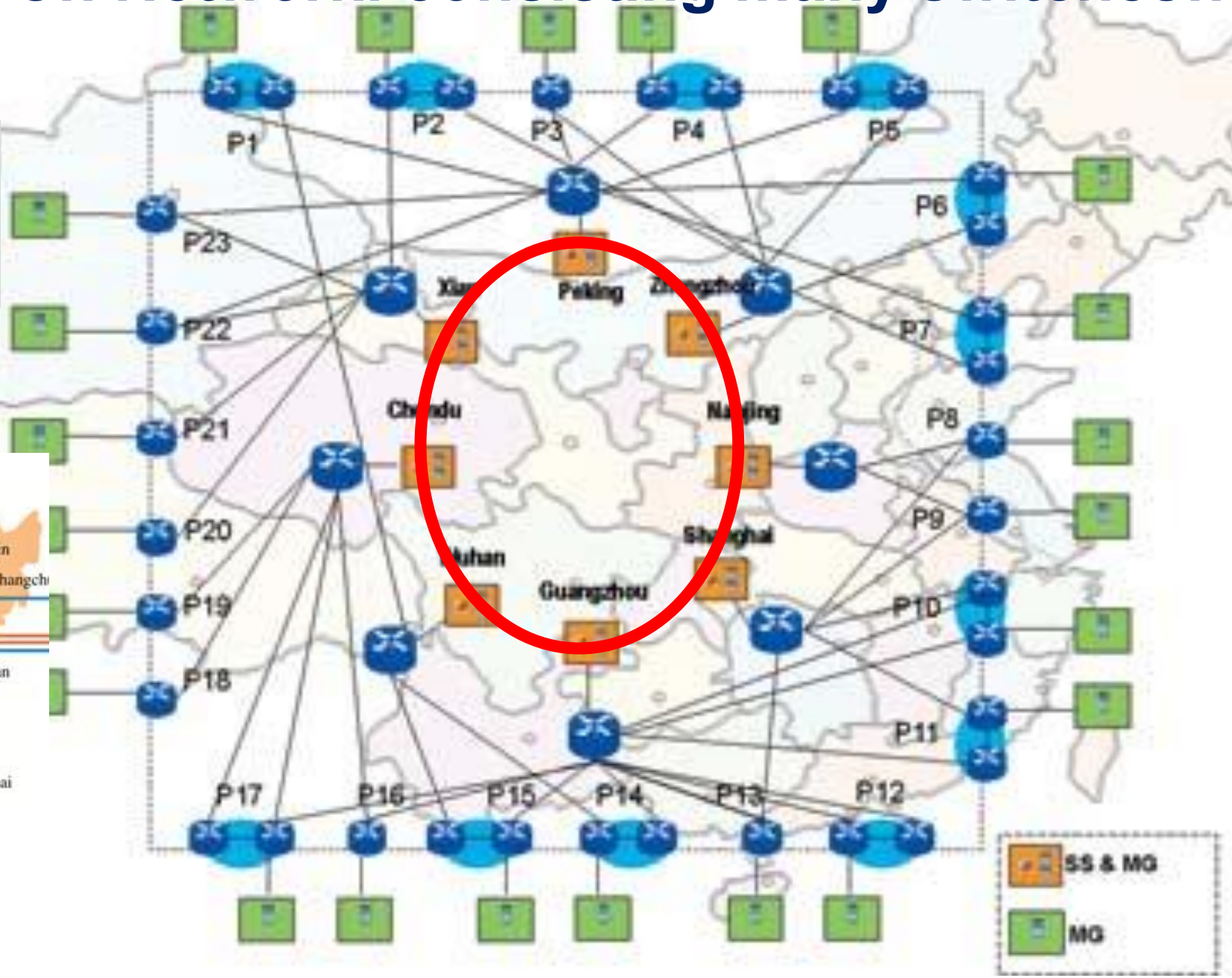
A telephone switch containing many ‘boards’

- Large telephone ‘switches’ could accommodate up to 3M subscriber lines (telephone lines) on boards

- A city like Chengdu might have several large switches connected to the digital network

Next Generation Cn Network: consisting many switches…

- One person's system is somebody else's component…



University of Glasgow

Groups of 4
10 minutes

Class Exercise

Working in groups of 4, discuss whether the following are systems or components…

1. A wireless microphone or Headset
2. A mobile phone
3. A fighter jet
4. An aircraft Carrier in the Chinese navy
5. A Hospital

Component ?	System ?

Write down who you think calls it a component and who thinks it is a system

(e.g. Laptop: User thinks it as a component, Intel think it as a system)

University of Glasgow

Electronic System Design

A Practical Example

1. Typical Customer Requirement

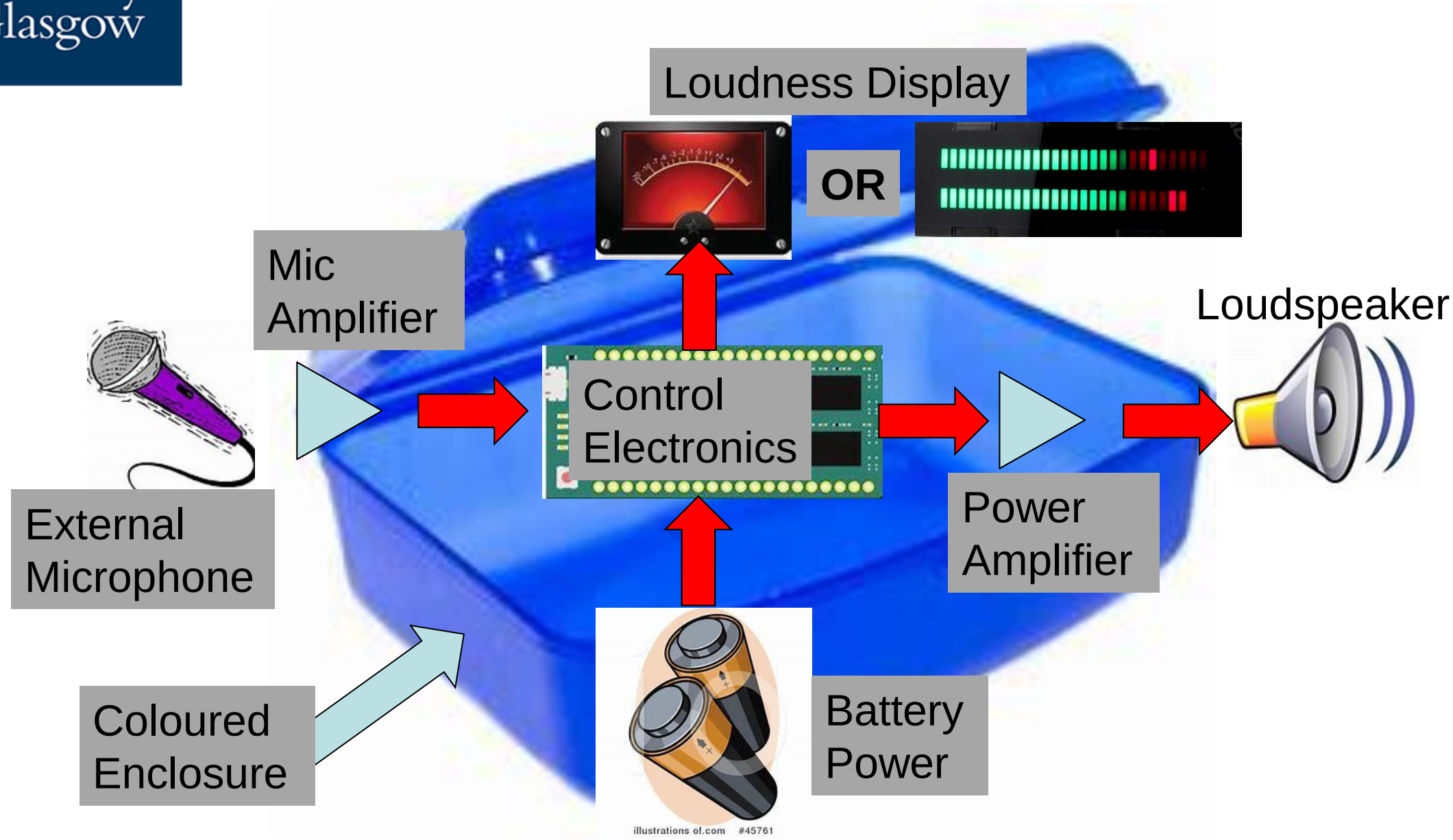
'I want a piece of electronics that will make my voice louder and sound better when I am singing along with my favourite songs on my phone'

1. It needs to be portable and battery powered
2. It needs a display to tell me how loud I am singing
3. I also want to be able to sell it to lecturers to improve their presentations
4. It must match my iPhone /XiaoMi /Huawei phone colours
5. It must be cheap….

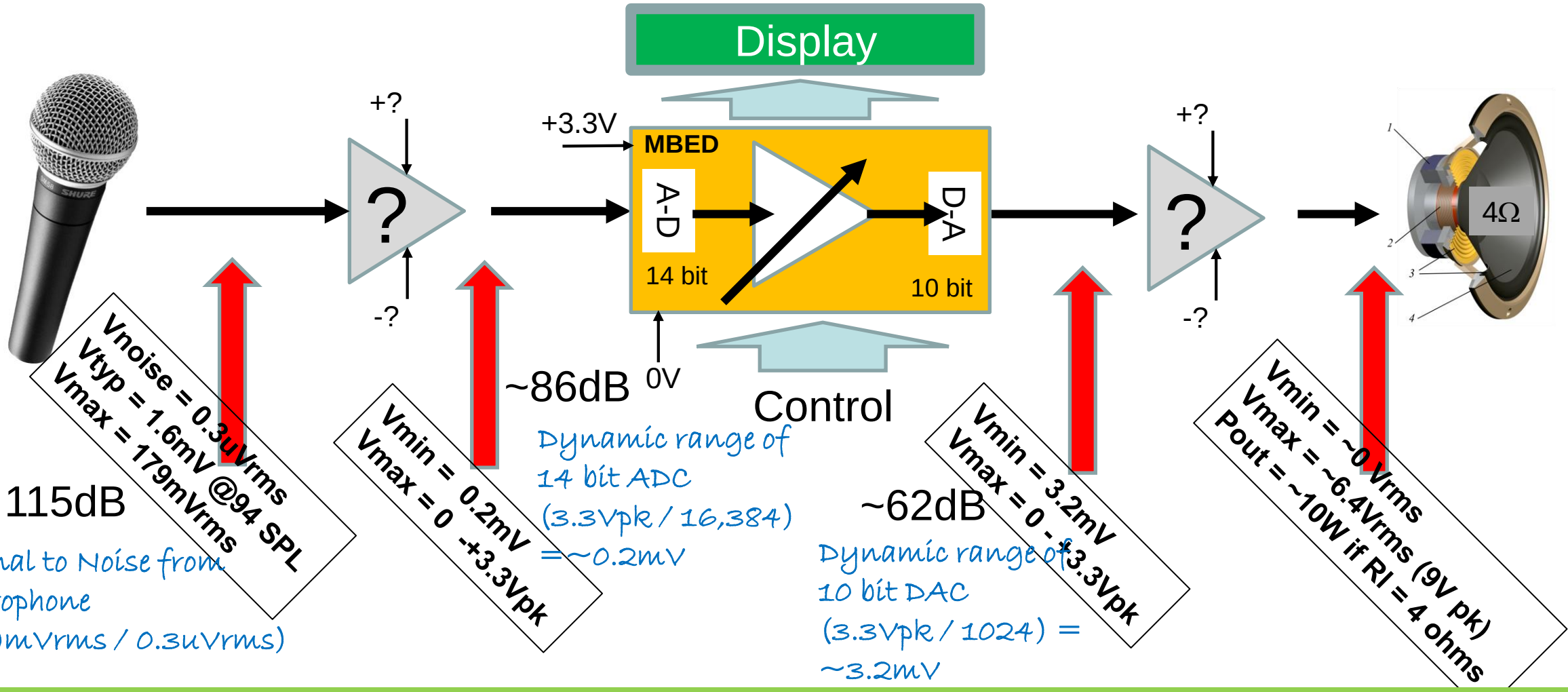
NOTE:- There is no mention of how many volts / amps / watts in this requirement

⇨ That is <u>your</u> job…

2. High Level, Concept Design

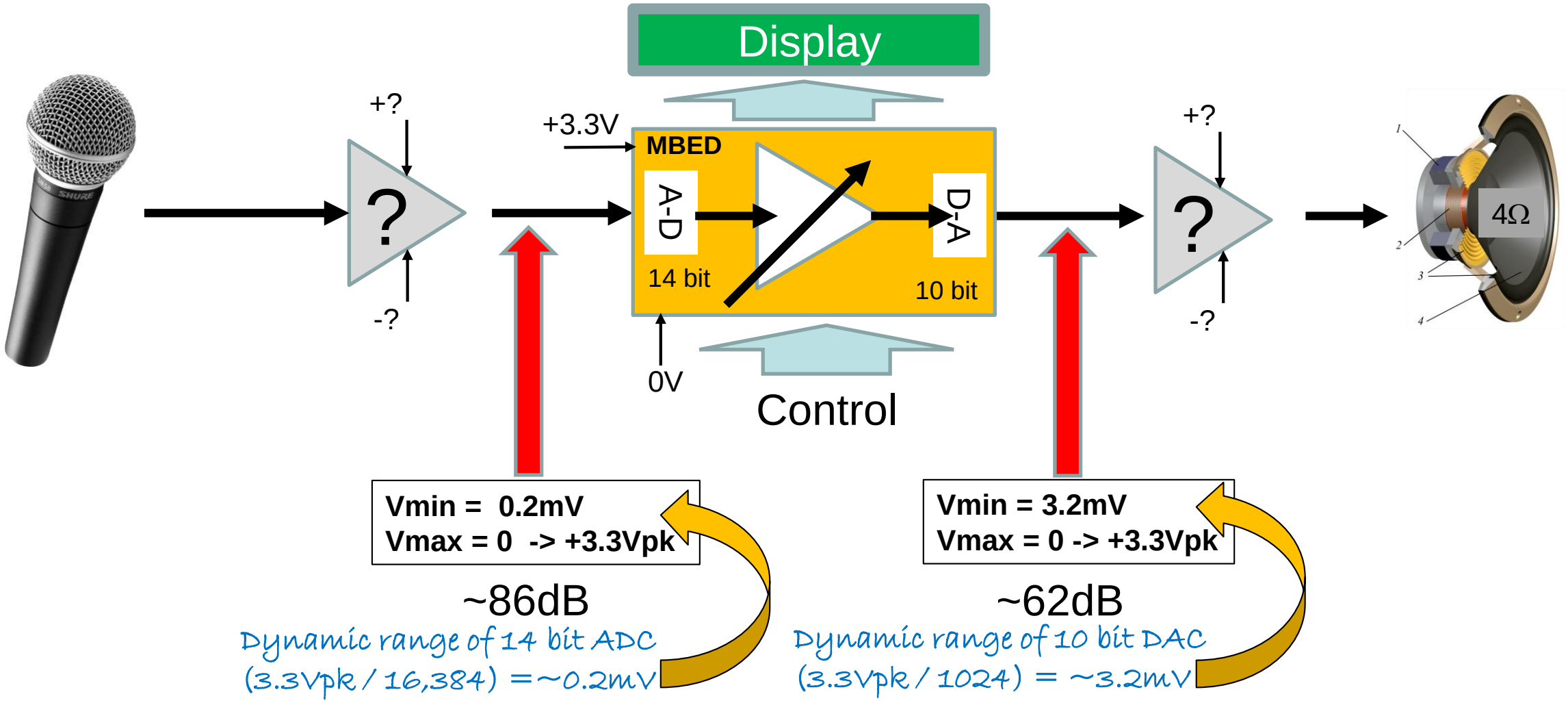


3. Examine the signal levels at the interfaces…



How do we design the system for best performance?

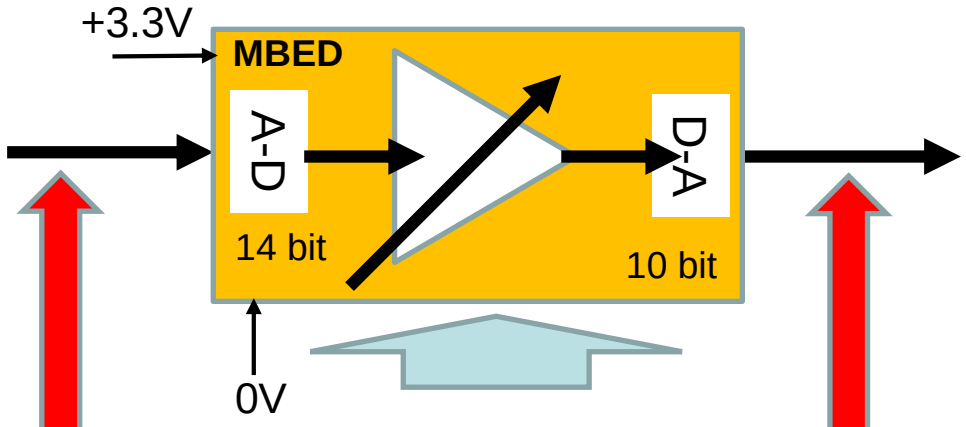
4. Identify the problem block(s)… usually the ones with the limited performance



4. Identify the problem block(s)… usually the ones with the limited performance

We cannot change the input parameters of the MBED ADC so it is a limitation

Answer: design around the limitation or replace… (difficult)



We cannot change the output parameters of the MBED DAC so it is a limitation

Answer: design around the limitation or replace… (difficult)

Vmin = 0.2mV
Vmax = 0 -+3.3Vpk

~86dB

Dynamic range of 14 bit ADC
(3.3Vpk / 16,384) =~0.2mV

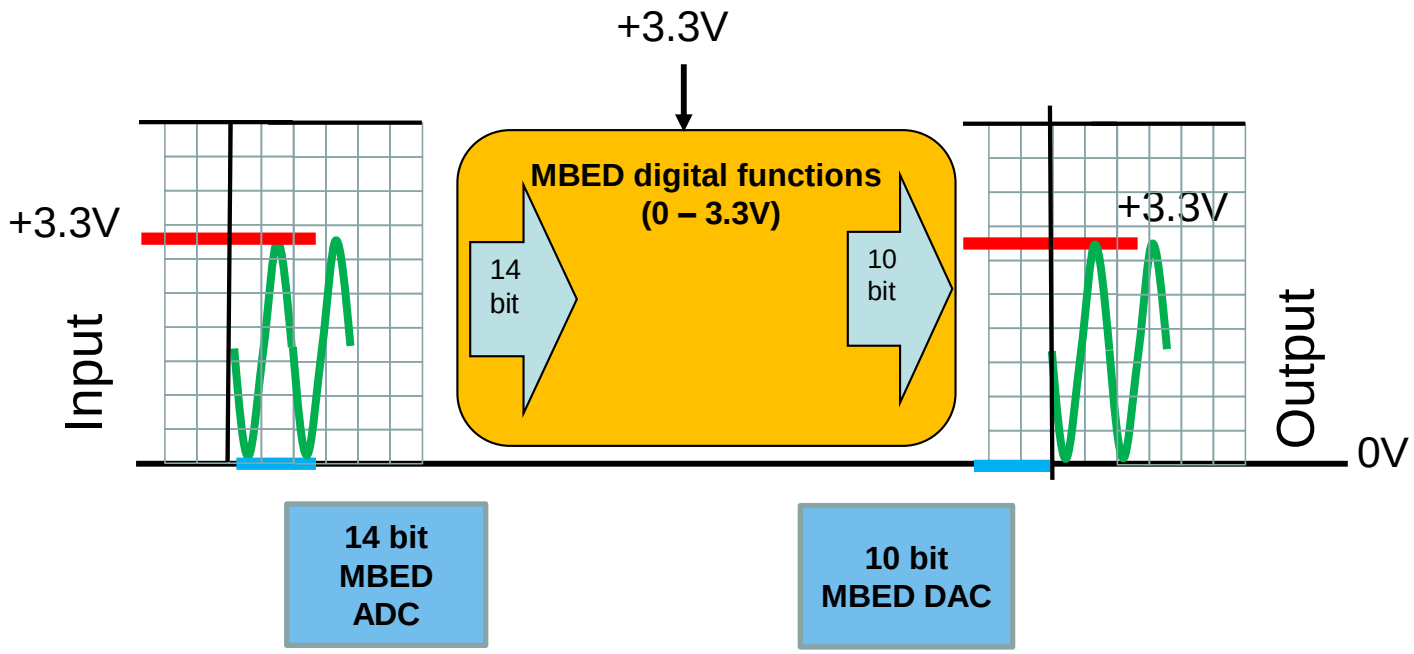
Vmin = 3.2mV
Vmax = 0 - +3.3Vpk

~62dB

Dynamic range of 10 bit DAC
(3.3Vpk / 1024) = ~3.2mV

Our system performance is going to be limited by the MBED ADC / DAC performance

5. Examine the signal levels around problem blocks…



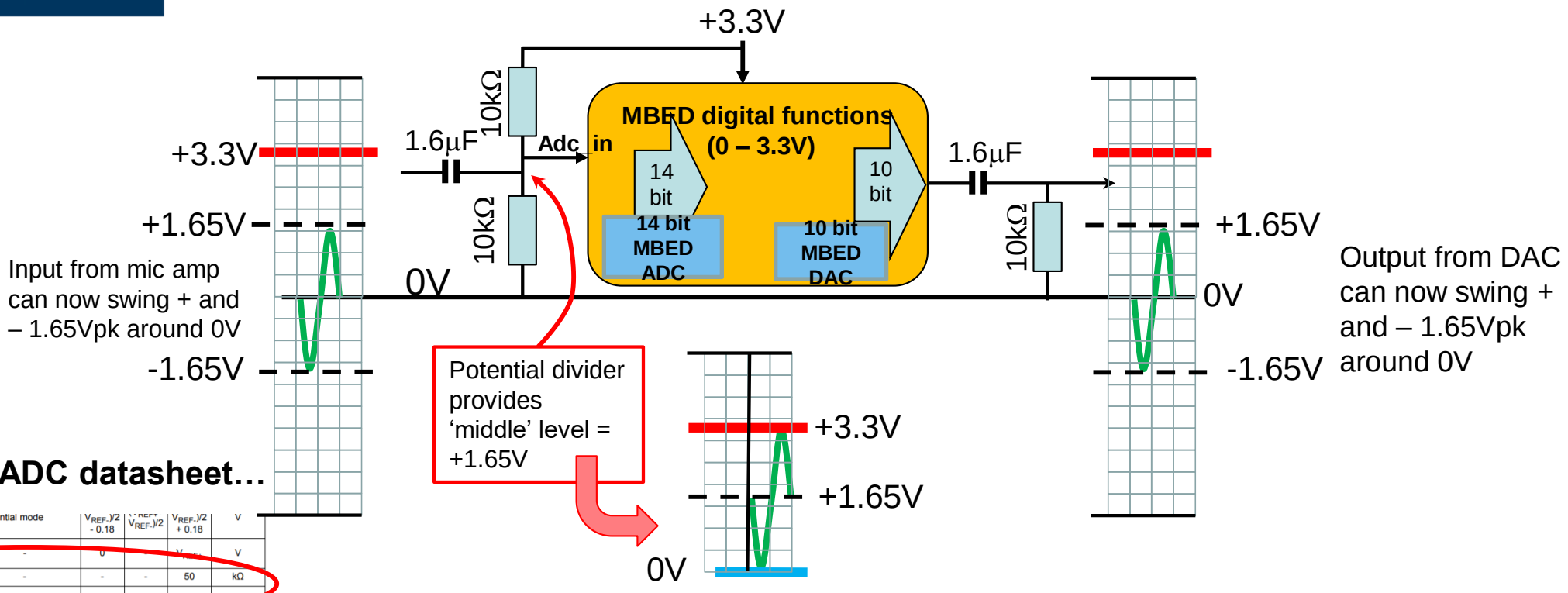
Vmin = 0.2mV (LSB)
Vmax = 0 ->+3.3Vpk

Vmin = 3.2mV (LSB)
Vmax = 0 -> +3.3Vpk

We have 3 key problems:

1. Input range of ADC is between 0V and +3.3V
2. Audio signals are (usually) centred around 0V (positive and negative peaks). We need to modify our circuit to deal with this; i.e. to accept an input centred around 0V
3. The output range of DAC is between 0 and +3.3V; we want to output a signal centred around 0V

6. Solve the problems…



Check the ADC datasheet…

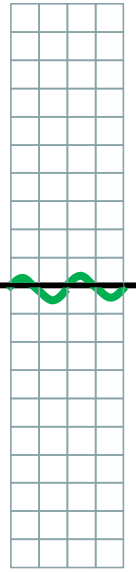
V_{CMIN}	Input common mode	Differential mode	$V_{REF-}/2$ - 0.18	$V_{REF-}/2$	$V_{REF-}/2$ + 0.18	V
V_{AIN} (3)	Conversion voltage range(2)	-	0		V_{REF+}	V
R_{AIN}	External input impedance	-	-	-	50	kΩ
	Internal sample and hold capacitor	-	-	5	-	pF
t_{STAB}	Power-up time	-		1		conversion cycle

We have 3 key problems:

1. Input range of ADC is between 0V and +3.3V **…Fixed**
2. Audio signals are (usually) centred around 0V (positive and negative peaks). We need to modify our circuit to deal with this; i.e. to accept an input centred around 0V **…Fixed**
3. The output range of DAC is between 0 and +3.3V; we want to output a signal centred around 0V **…Fixed**

7. Introduce the other blocks to the system…

Design value for maximum signal = 1.6mVrms (94dBA) ==2.26mVpk



Input

Input Amplifier

0V

+3.3V

Output

1.6µF

10kΩ

10kΩ

MBED ADC

MBED DAC

MBED digital functions

1.6µF

10kΩ

Input Amp gain = 1.65Vpk / 2.26mVpk = x 730 or 57.2dB

Control

Display

Input

Power Amplifier

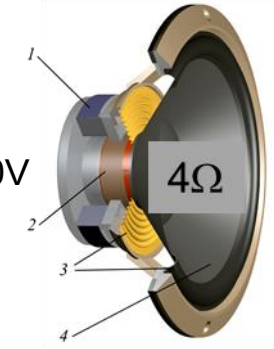
Output

+10V

0V

-10V

Power Amp gain = 9.0Vpk / 1.65Vpk = x 5.45 or 14.7dB



Design value for required output power = 10Wrms ~6.4 Vrms [+/- 9.0Vpk]

Finally… choose your power supplies

- **After you have designed for the correct signal levels, look at the power supplies you will need**
  - The input amplifier needs V+, V- to produce +/- 1.65Vpk output We have relatively free choice; let's assume +/- 3.3V
  - The MBED is constrained for a maximum supply of +3.6V (use +3.3V to be safe)
  - If MBED is running on +3.3V then design all logic around this value
  - The output Amplifier needs +/- 10V to produce +/- 9V pk output into 4 W (+/- 2.25Amps) *[Power amp needs 1V headroom to operate]*

- **In some designs (e.g. automotive) you might be constrained by the available supplies**

Typical System design ‘Customer Questions’

Assuming the main components are fixed (microphone, mic amp, MBED, power amp, loudspeaker etc)

- *How large a battery would be required for it to last 1 x 2 hour lecture?*
  - **Typical ‘talking’ voice SPL = 94dBA (1.6mVrms)**
- *How long would the same battery last if was used in a rock concert?*
  - **Typical ‘screaming singing’ voice SPL = 135dBA (at 25mm) [179mVrms]**
- *If Output Power = 6.4Vrms into a 4 ohm loudspeaker [10Wrms], do we require a heatsink on a iPhone? How large?*
- *Am I allowed to take this equipment on a commercial airline flight ?*
- **These are ‘typical’ system design questions:- they do not ‘sound’ technical, but you need to perform a full engineering analysis to get the right answer!!**

University of Glasgow

6 Rules for System Designers

1. Find out what the customer is trying to do (NOT what they say they want to do!!)
2. Agree a set of requirements with the customer of what you will do to meet their need
3. Think about the WHOLE problem and identify major tasks / functions / blocks you need to perform the task
4. Look at the interfaces; what is happening BETWEEN the blocks
5. Look at the physical limitations (power, signal levels, heat etc)
6. Think about VALIDATION and VERIFICATION; how will you prove you have met the requirements

Self Study Question: How many bits do you need?

If you use a typical dynamic microphone (Shure SM57) which has a maximum output of 179mV, and a noise level of 0.3uVrms

1. What is theoretical dynamic range? [using DR = 20 log (Vmax / Vnoise)]
2. How many bits ? [using DR =(6.02*N) + 1.76 in dB]
3. Should you invest in 24 bit ADCs for audio recording using this microphone?


University of Glasgow
Thank you
谢谢
INSPIRING PEOPLE
#UofGWorldChangers
@UofGlasgow