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Electronic System Design
A Practical Example
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WORLD CHANGING GLASGOW

# 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…

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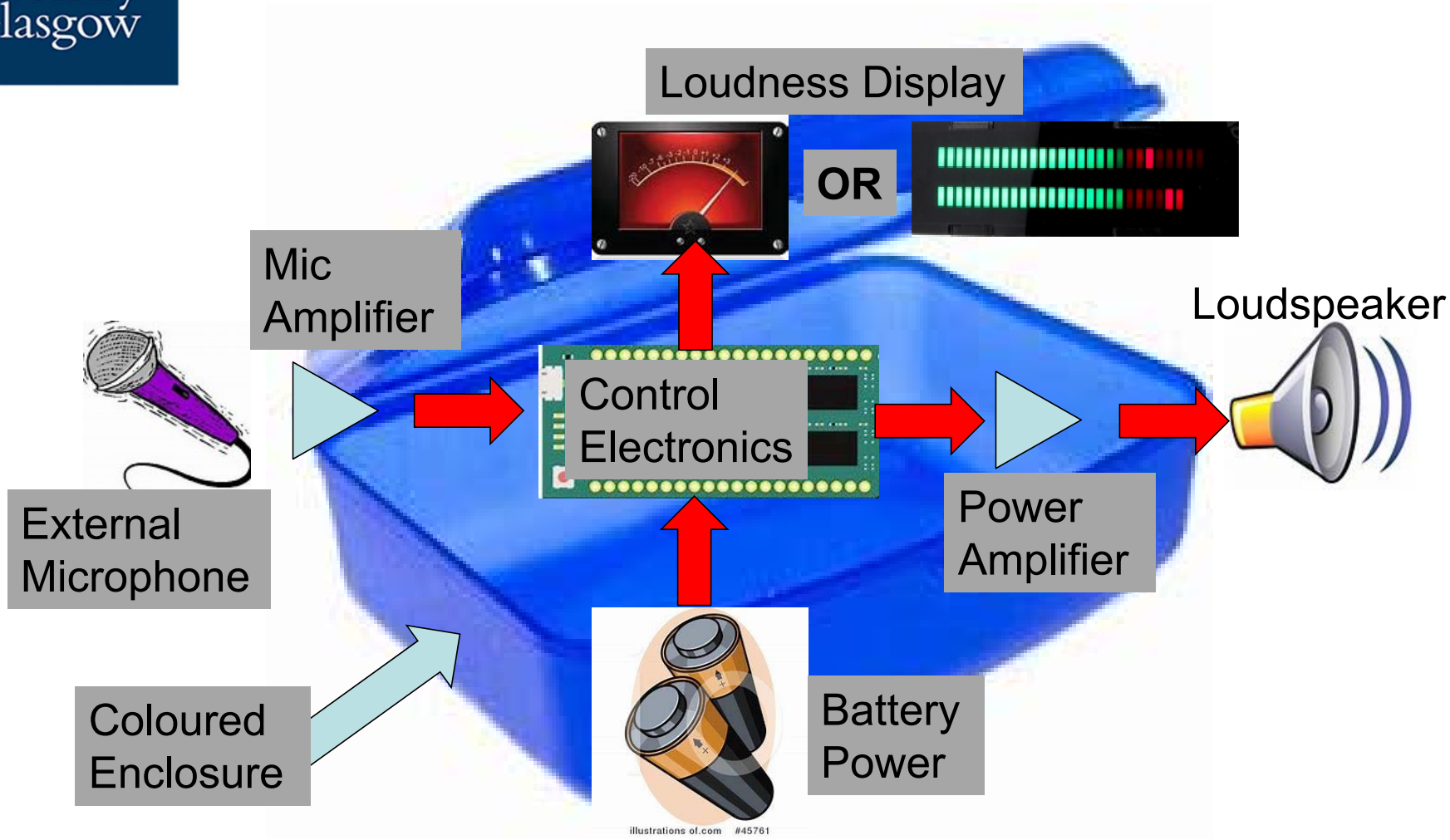
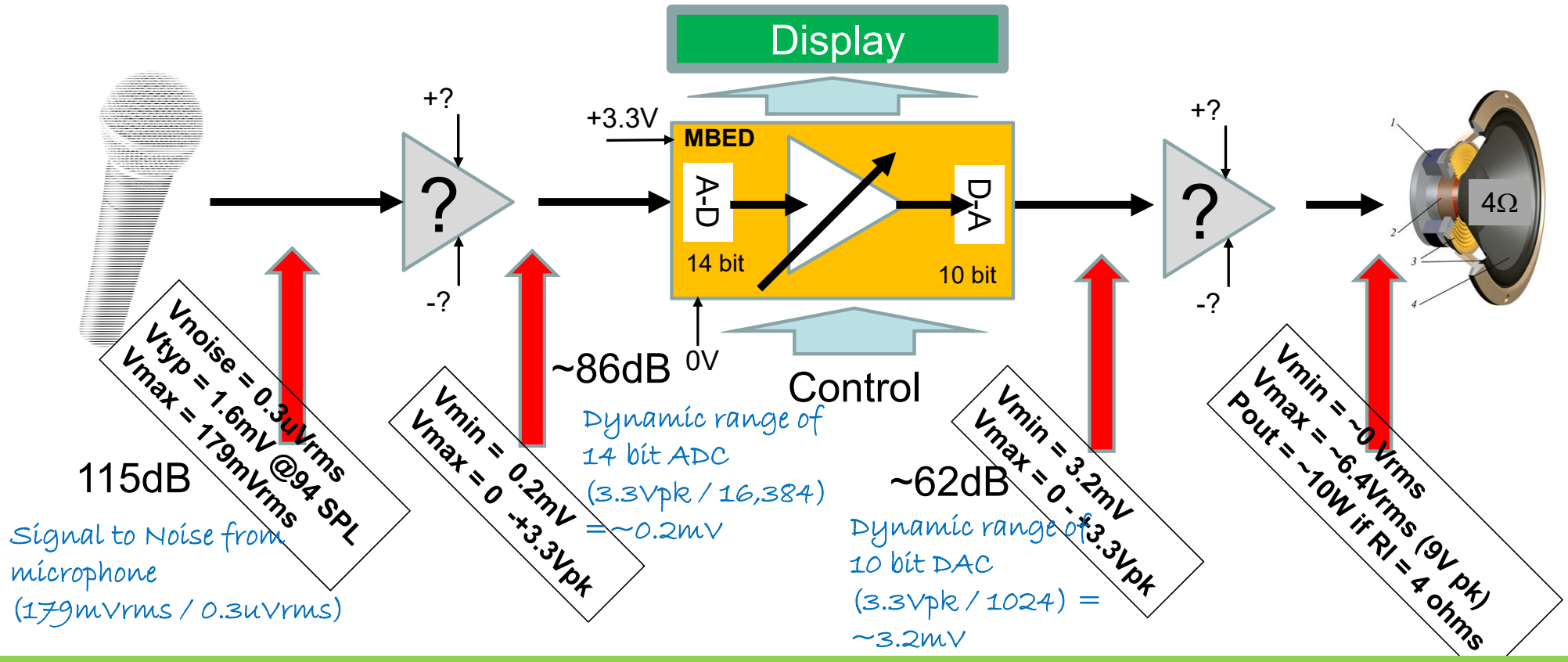
# 2. High Level, Concept Design

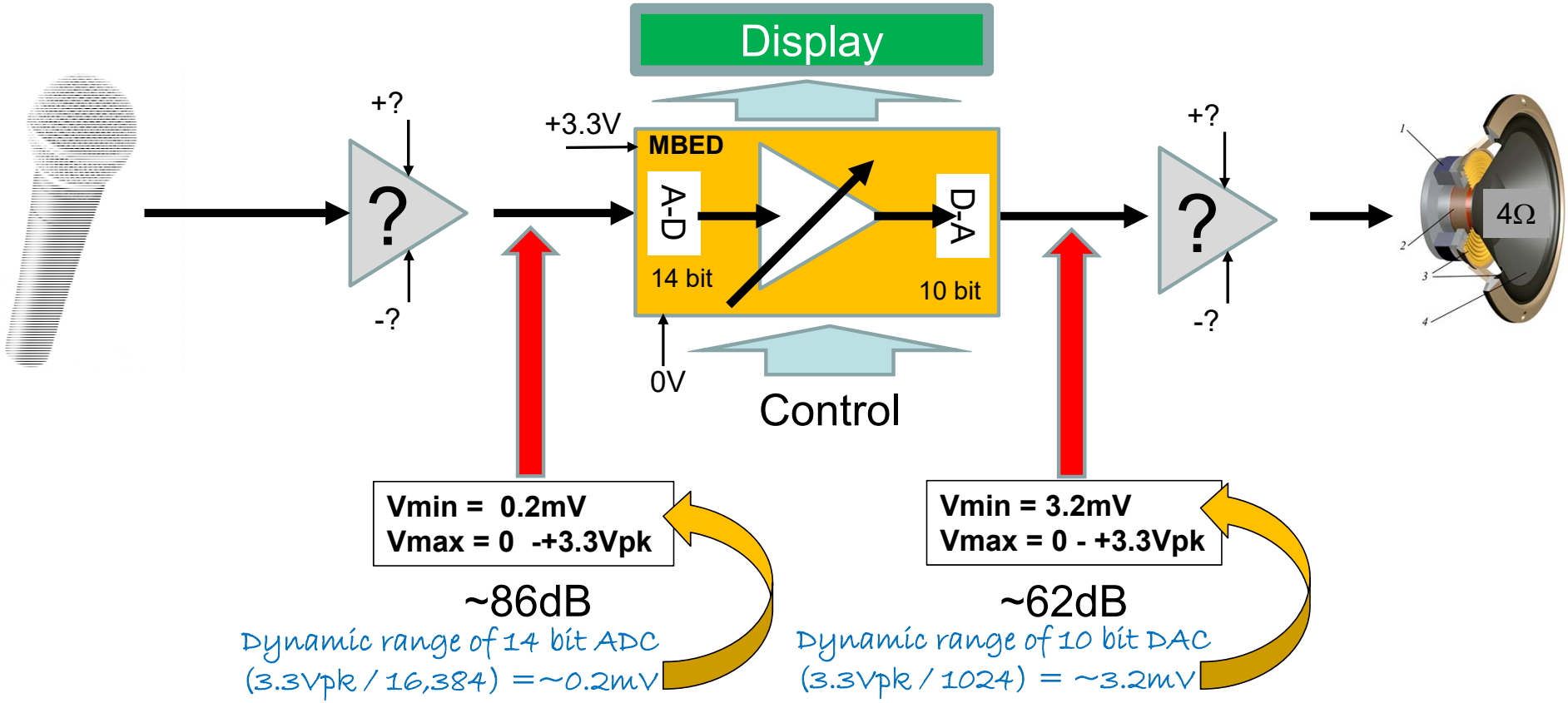


# 3. Examine the signal levels at the interfaces…




How do we design the system for best performance?

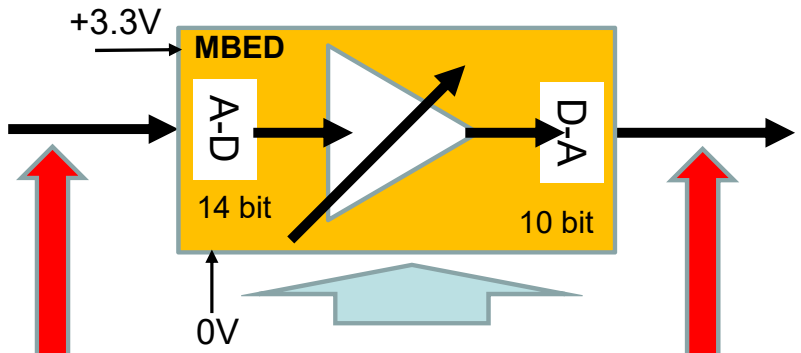
# 4. Identify the problem block(s)… usually the ones with the limited performance



# 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

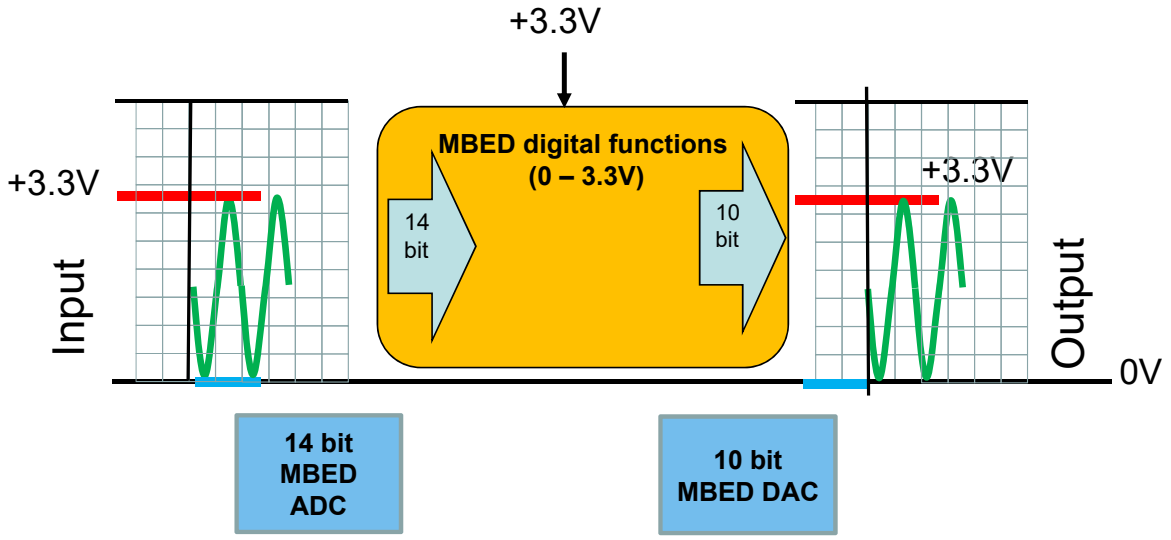
**Vmin = 3.2mV**
**Vmax = 0 - +3.3Vpk**

~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…



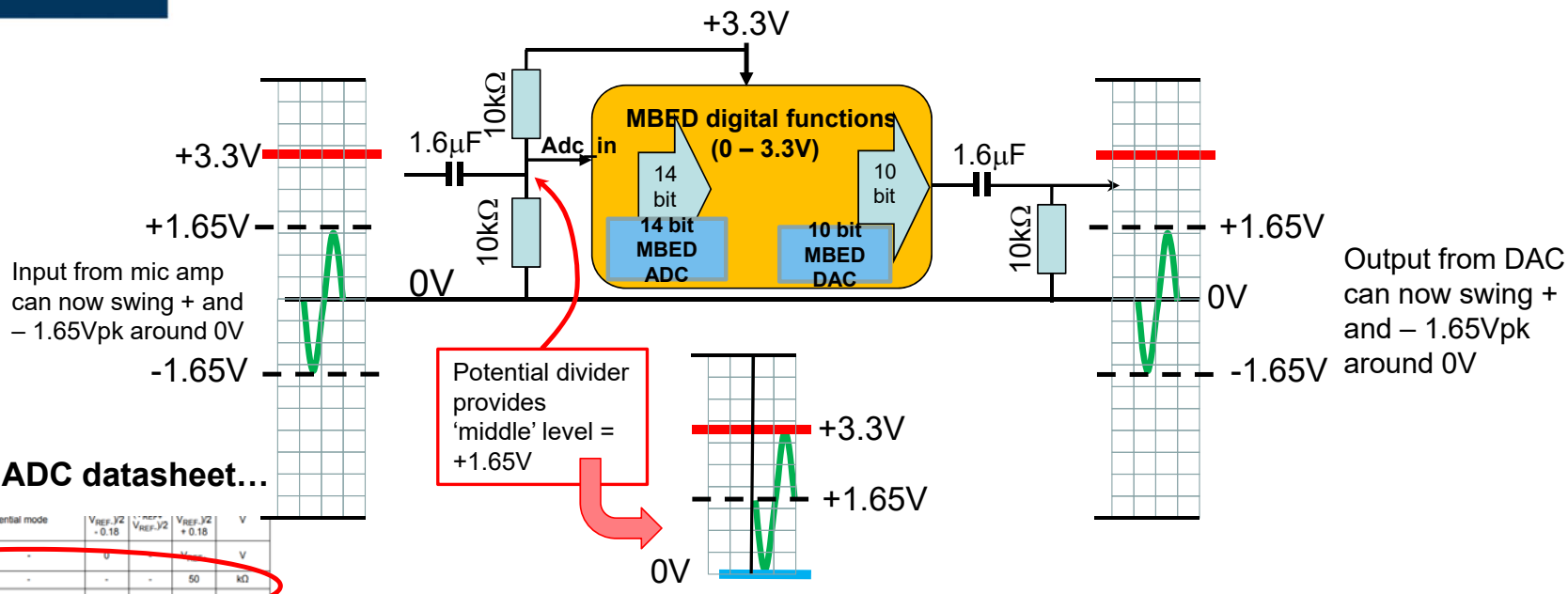

**Vmin = 0.2mV (LSB)**
**Vmax = 0 ->+3.3Vpk**

**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…**

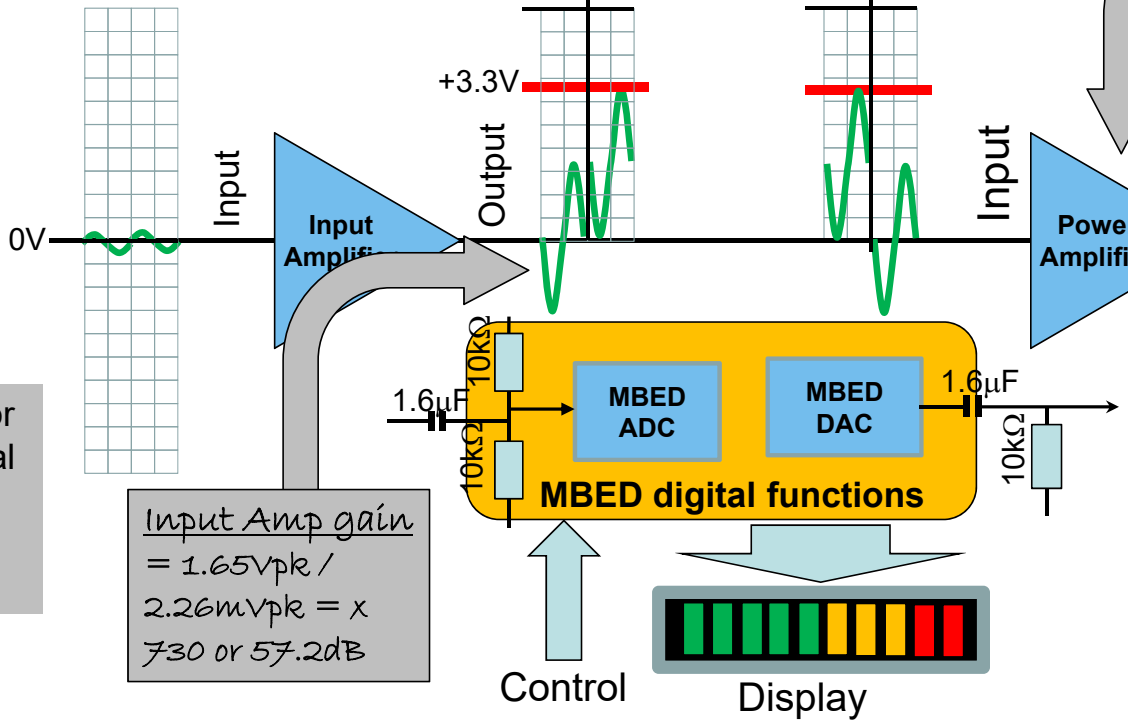
| | | | | | | |
|---|---|---|---|---|---|---|
| $V_{CMIN}$ | Input common mode | Differential mode | $V_{REF-}/2$ - 0.18 | $V_{REF-}/2$ | $V_{REF-}/2$ + 0.18 | V |
| $V_{AIN}$ (3) | Conversion voltage range(2) | - | 0 | | $V_{REF+}$ | V |
| $R_{AIN}$ | External input impedance | - | - | - | 50 | kΩ |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

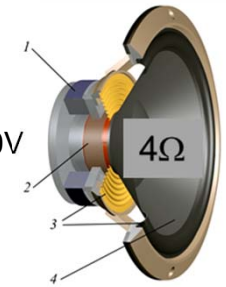
**We have 3 key problems:**

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




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

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# 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!!**

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# 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


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Thank you
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# 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?

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# Self Study Question (Answer)

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? [115.5dB]

2. How many bits ? [using DR =(6.02*N) + 1.76 in dB] [19bit]

3. Should you invest in 24 bit ADCs for audio? [No]
   - Why: because we have just shown we only need about 19 bits to do the task…
   - Important: this was not a ‘guess’ it was a careful calculation


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https://www.bing.com/videos/search?q=road+traffic+management+system+chengdu+china&&view=detail&mid=16DFF82082976D9C8D9A16DFF82082976D9C8D9A&&FORM=VRDGAR&ru=%2Fvideos%2Fsearch%3Fq%3Droad%2520traffic%2520management%2520system%2520chengdu%2520china%26qs%3Dn%26form%3DQBVR%26sp%3D-1%26pq%3Droad%2520traffic%2520management%2520system%2520chengdu%2520china%26sc%3D0-44%26sk%3D%26cvid%3D919404EFE5BD4C3198944A79CB6431AE

**Land rover** https://www.youtube.com/watch?v=KTxOB8CjmlU

https://www.youtube.com/watch?v=VSJM5xpLj0M

**Chengdu traffic management**

https://www.worldbank.org/en/news/feature/2018/11/16/reducing-traffic-congestion-and-emission-in-chinese-cities

**High Speed Railway (Automated)**

https://www.youtube.com/watch?v=wCc0aH68BTs&list=PLvi9k6lKscdiBdDiwQMyBh-nH9A21YV0z&index=1168

**Airbus autoland** https://www.youtube.com/watch?v=V0OJ-rPDXNs

**Auto takeoff** https://youtu.be/9TIBeso4abU

**F1 Mercedes team** https://www.youtube.com/watch?v=ilj6fp54YS4

**Micra Advert**

https://www.adsoftheworld.com/media/film/nissan_new_nissan_micra_nsport_where_to_next_intelligent_trace_control

**Gandalf nods** https://www.youtube.com/watch?v=2rCP4CRRO7E

**Gandalf quotes 'small things'** https://www.youtube.com/watch?v=dG2UO2F0iY4

**Gandalf you shall not pass** https://www.youtube.com/watch?v=VlaiBeLrntQ