Development and Analysis of Power Behavior for Embedded System Laboratory

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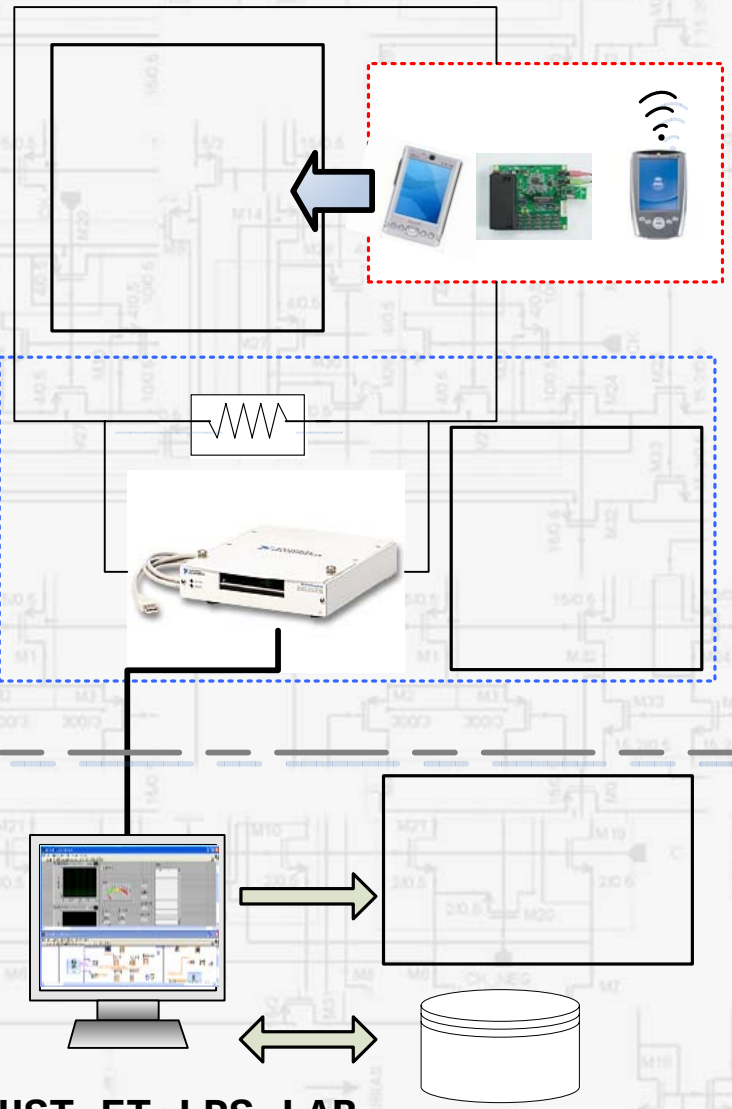
Outline

- Introduction
- Power Measurement System
- Using DAQ System to Build Power Measurement Modules
  - Power Analysis of an Actual PDA
  - Power Behavior of Software Algorithm
  - Power Analysis of Wireless Communication
- Conclusion

Introduction

- Embedded computer systems are used in a diverse range of products such as PDAs, cell phones …
- Understand power behaviors of embedded systems is necessary for EE and CSE students.
- We devise a laboratory course to provide the basic concepts of low power design and system power management starting with power management system construction.
- Three experiments are introduced in this course:
  - Power analysis of various power modes in an actual PDA
  - Power behavior of running real game on a PDA
  - Power analysis of wireless Internet telephony

Power Measurement Flow



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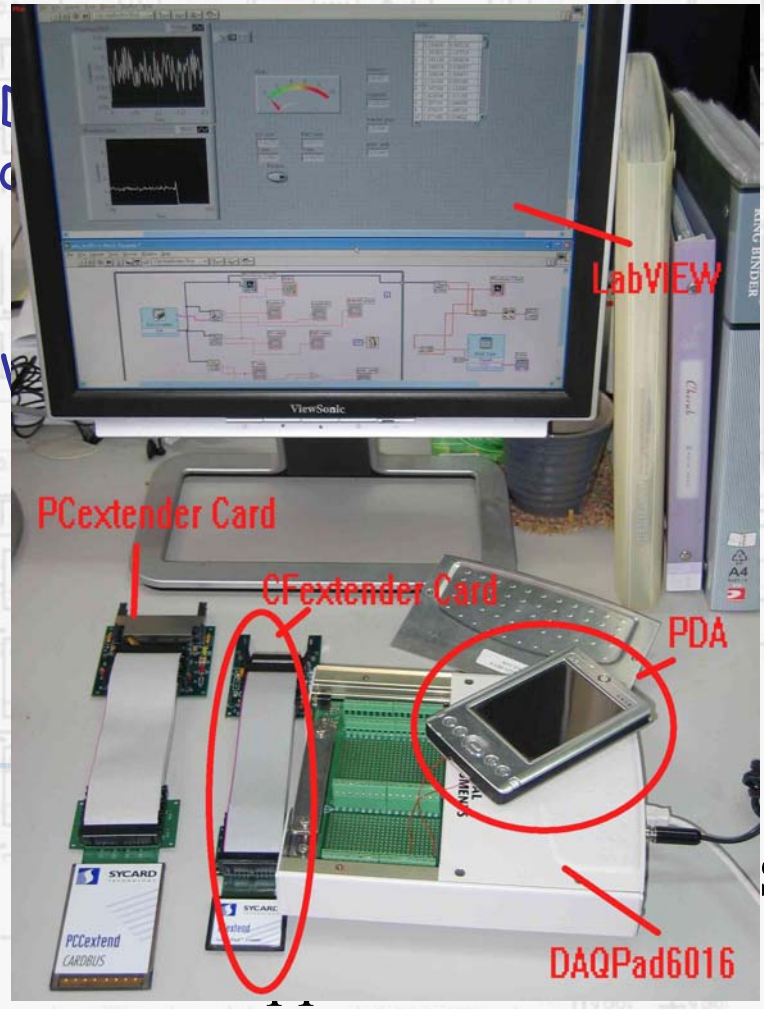
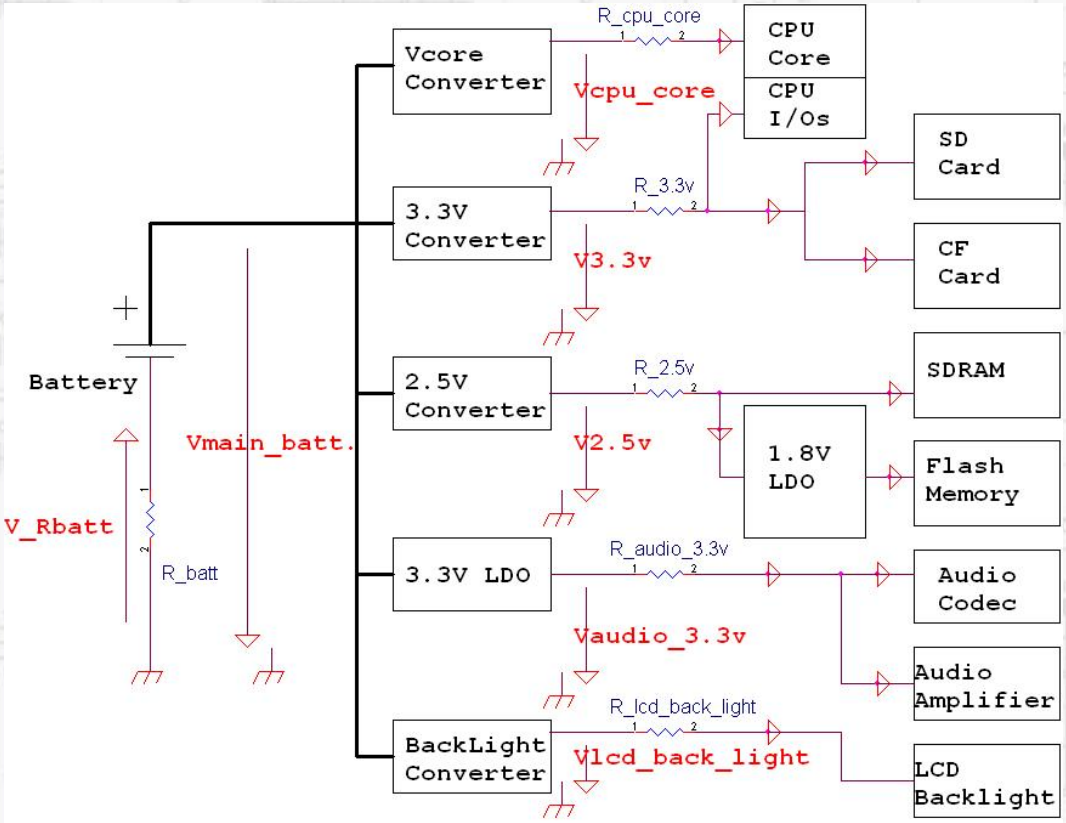


PDA

2. The Core Processor

Power Measurement of an Actual PDA



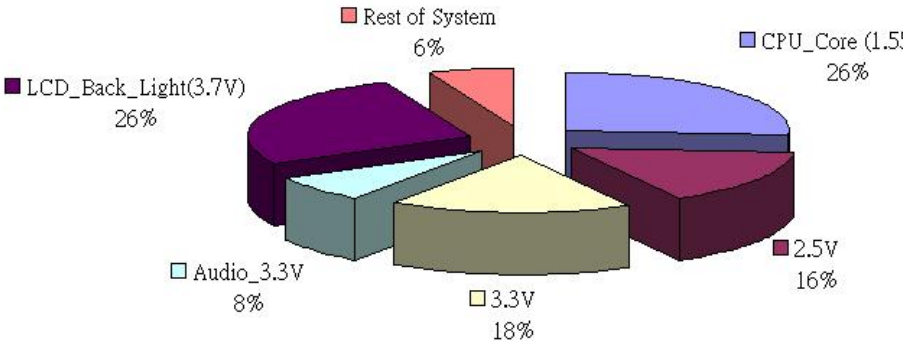
$$P_{Inst} = \frac{V_R}{R} \times V_{PowerSupply}$$

$$P_{avg.} = \sum_{\Delta t} P_{Inst} / T_{total}$$

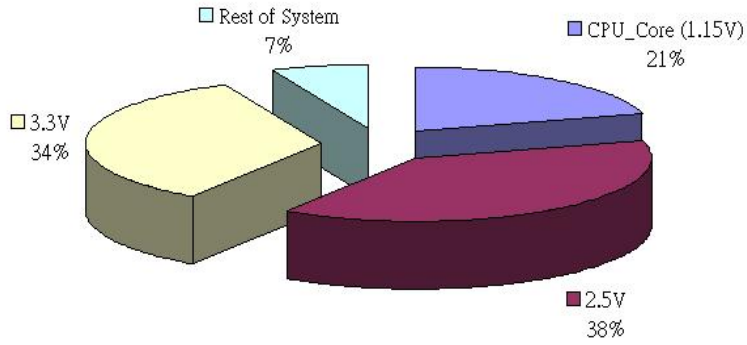
Power rails of Dell AXIM X50 PDA system

$$P_{total} = P_{CPU} + P_{2.5V} + P_{3.3V} + P_{Aud\_3.3} + P_{LCD} + P_{rest}$$

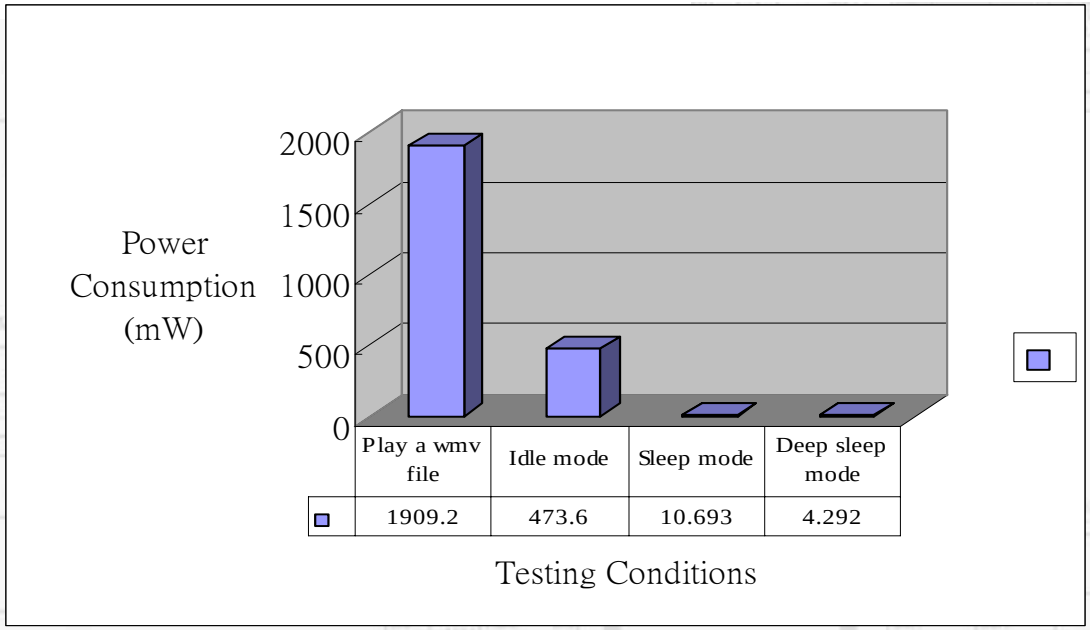
Average Power Consumption Breakdown for Different Modes of PDA



Average power breakdown when playing WMV file



Average power breakdown in idle mode



Power Analysis of Computer Games Algorithms

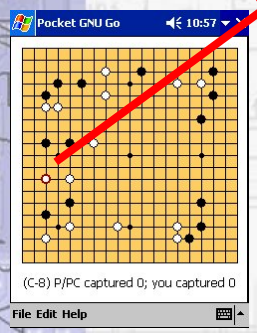
- Power Analysis of Computer Games Algorithms
  - The table summarizes the results from both factors of the study – load bitmap image size and the graphic frame rate of the game set.

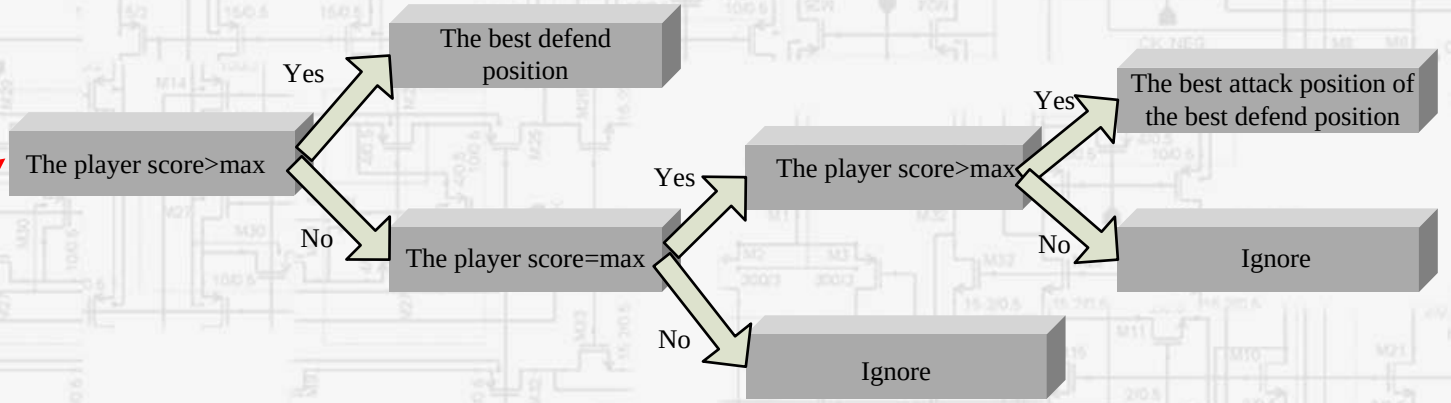
The graphic operation impact

Benchmark	Bitmap Image Size 32*32		Bitmap Image Size 64*64		Bitmap Image Size 192*192	
	Actual frame rate(fps)	Avg. Battery Power(mW)	Actual frame rate(fps)	Avg. Battery Power(mW)	Actual frame rate(fps)	Avg. Battery Power(mW)
Frame_rate1	1	425.33	1	431.61	1	434.61
Frame_rate5	5~6	435.36	5	451.49	3	495.14
Frame_rate20	20	487.29	18~19	473.66	3	489.67

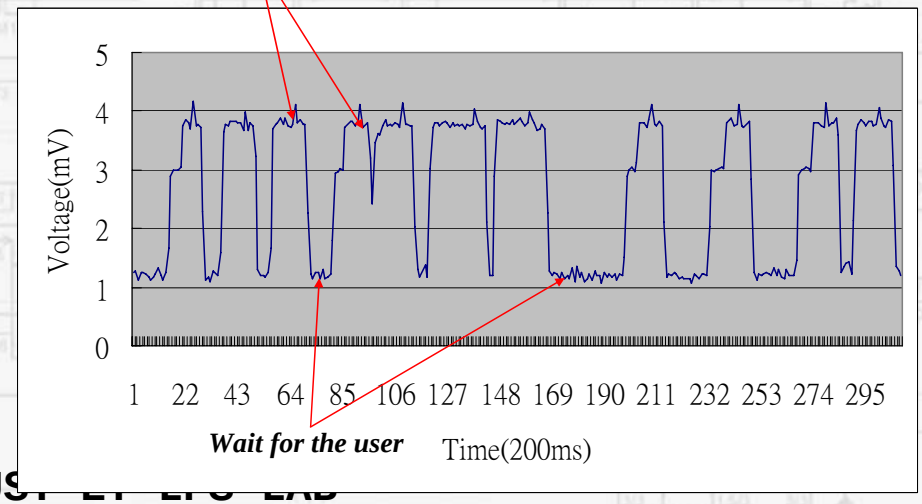
Power Behaviour in General Board Game AI

Depending on the game types the core processor of PDA consumes power in some regular behavior. The power behavior of various games can also be analyzed in the same way.





AI decision tree for a typical board game



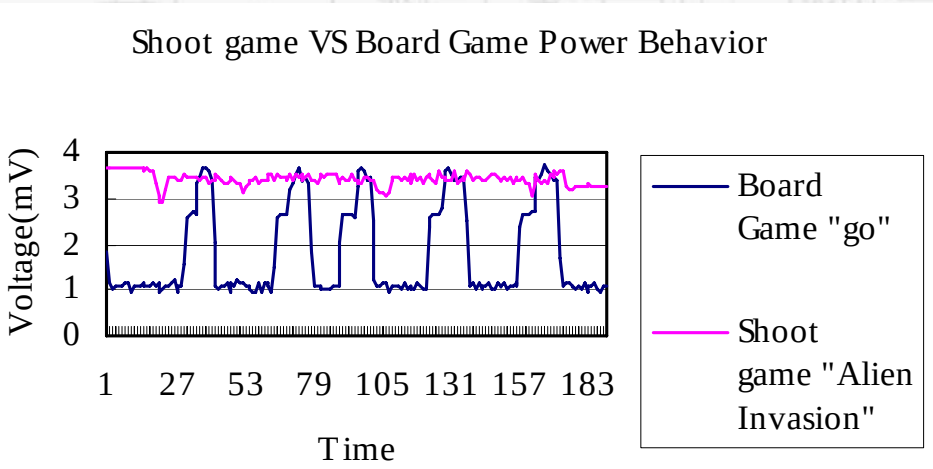
As can be seen from the left figure, the power represents fairly high when the game AI calculating score and comparison the game rules.

Power Behaviour in Different Computer Games (1/2)

Power effect for writing a game with different methods

Game	Design Method	Avg. CPU power(mW)	Avg. Battery Power(mW)
Blackout1	Game Library	241.00	802.22
Blackout2	WinCE API	152.20	662.80

AI used in shoot games such as sprites, collision detection, and game rules produced plenty of workload and caused the processor always in high power state.



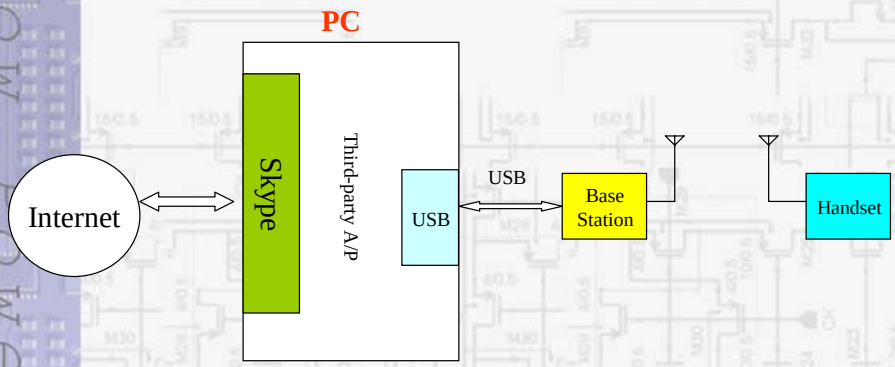
Power Comparison of Different Games

Game	Major algorithm	Avg. CPU power(mW)	Peak battery power consumption(mW)	Avg. Battery Power(mW)
Alien Invasion	Collision detection Animation display	266.57	832	663.84
GnuGo	Calculating the next position	136.17	752	422.56
Blackout	Animation display use the game library	241.00	804	802.22
Blackout2	Animation display without game library	152.20	716	662.80
Bubble	Neighbor compare	101.99	400	312.86
GravCave	Drawing terrain Collision detection	284.86	972	608.15
Tank Battle	Computer opponent Animation display	254.72	1008	632.61
Meteoroids	Gravity calculation, Animation display	252.40	900	707.04

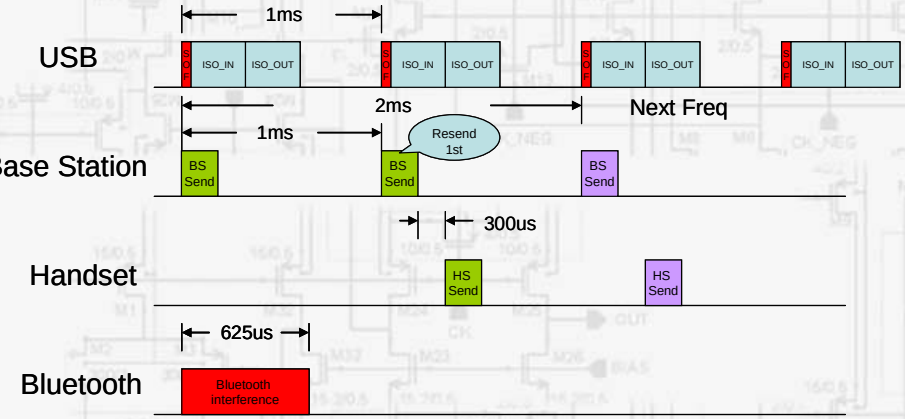
Power Analysis of a 2.4GHz Wireless Skype Phone (1/3)

- The wireless Skype phone is designed and implemented by our research group for education.
- Features
  - Our wireless Skype phone can also dial out by its hand-set device.
  - Using Nordic nRF2401 as the RF transceiver
    - output power and frequency channels are easily programmable
  - Frequency hopping technology is used to avoid radio interference.

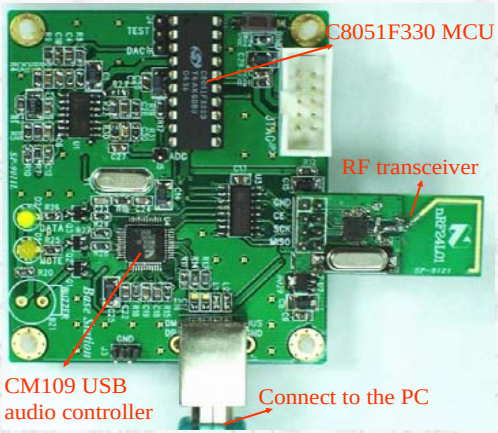
Power Analysis of a 2.4GHz Wireless Skype Phone (2/3)



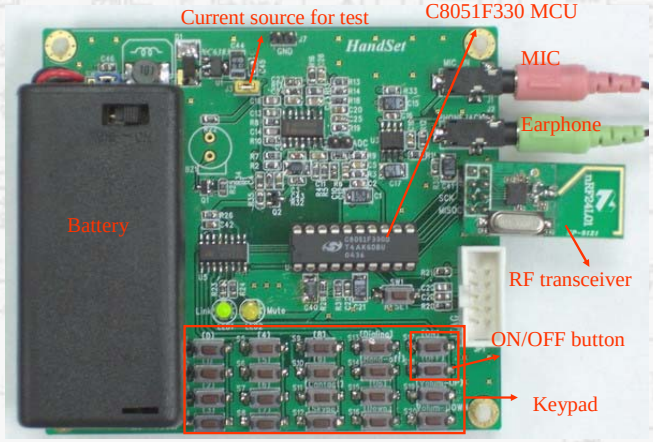
The architecture of the developed system



The communication protocols



Base station



Handset

Power Analysis of a 2.4GHz Wireless Skype Phone (3/3)

- Students can learn about how to improve the example program and compare with bluetooth products.
- Students can compare the power behaviors between hopping and non-hopping versions
- Students begin with the default communication system, they can try to improve the framework of the example protocol and apply other possible techniques to reduce power consumption.
- The speech compression, fault-tolerance, advanced data transmission mechanism or other method about power reduction can be the project topics.

Conclusions

- The primary objective of the laboratory is to deliver the understanding of system-level power analysis.
- We provide student with the methodology for finding the characteristics of the power consumption and the power behavior of a system.
- It is very useful for them to engage on further research projects related to low power system design.
- Students can observe the power behavior of an embedded system and find out the key factors of the power consumption through three experiments.
  - Power measurements of an actual PDA
  - Energy effect by different algorithms running on a PDA
  - Power analysis of wireless Skype phone

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