Optimized Mobile System Power

"Exact Power @ Exact Time"

PWRSoC 2016

Session 8: Granular Power

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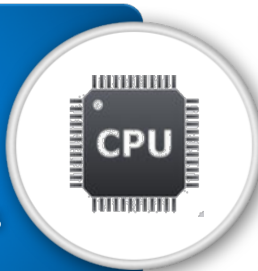
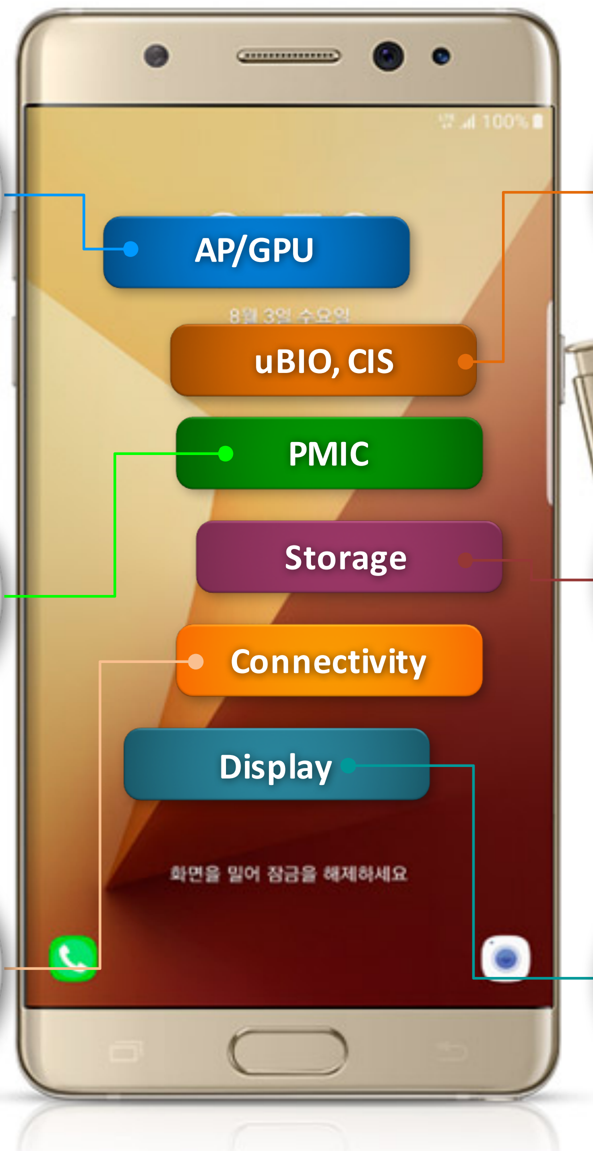
Contents

- Mobile System Contents & Teardown
- System Power and Connectivity
- Power Delivery and Si Technology Trends
- System Power Management & Sequencing
- Putting it altogether!

Typical Smart Phone System Contents

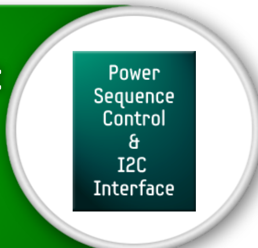
- **Apps Processor**
  - 14nm Quad-Core
- **Graphics Processor**
  - Capable of 4K @ 60fps





- **BIO Processor**
  - 1-Chip Solution
- **Sensor Modules**
  - CAM & IRIS Modules
  - Bio Sensors

- **Power Management**
  - PFM/PWM
  - Multi-Phase
  - Thin and Tiny



- eMMC
- UFS
- DDR

- **Cellular** (LTE-A)
- **WiFi** (802.11abgn)
- **BLE-4.1**
- **GNSS** (Quad mode)

- **AMOLED**
  - 5.7” QHD (2560x1440)
  - RES = 3.7M-pixels

Typical Wearable System Contents

- **Apps Processor**
  - 14nm 2x-Core @ 1GHz
- **Graphics Processor**
  - Capable of 4K @ 60fps

- **Power Management**
  - PFM/PWM
  - Thin and Tiny
- **Battery Management**
  - WPC Inductive

- **WiFi** (802.11bgn)
- **BLE-4.2**
- **NFC, MST, GPS**
- **Glonass**

- **BIO Processor**
  - Accelerometer
  - Gyro, Barometer
  - HRM, Ambient Light

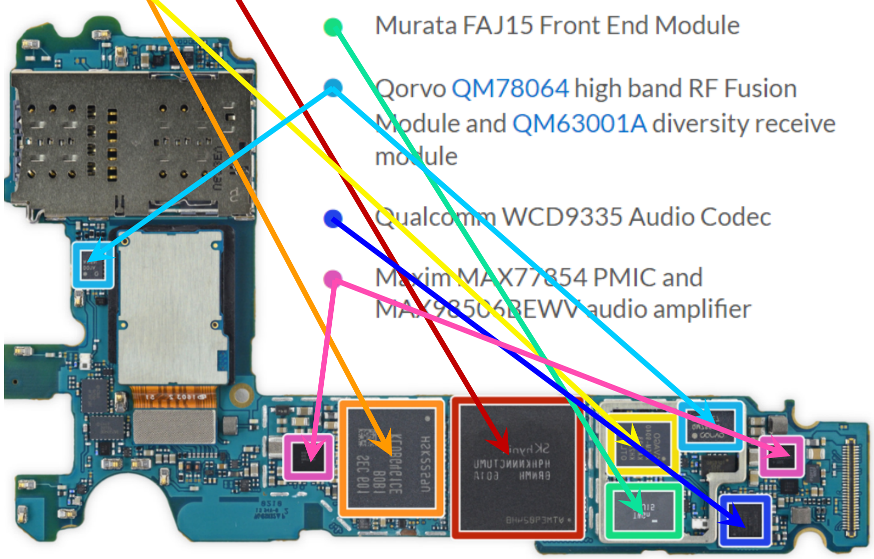
- **UFS**
  - 4GB
- **DDR**
  - 768MB

- **AMOLED**
  - 1.3” Always-ON
  - 360x360 @ 278ppi

Galaxy S7-Edge Teardown

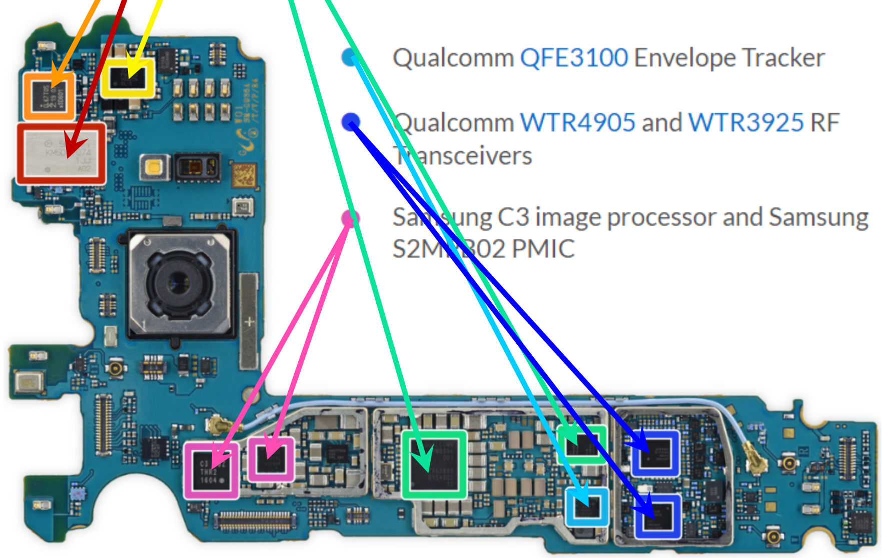
Galaxy S7-Edge Platform Front-Side

- SK Hynix H9KNNNCTUMU-BRNMH 4 GB LPDDR4 SDRAM layered over the Qualcomm MSM8996 Snapdragon 820
- Samsung KLUBG4G1CE 32 GB MLC Universal Flash Storage 2.0
- Avago AFEM-9040 Multiband Multimode Module
- Murata FAJ15 Front End Module
- Qorvo QM78064 high band RF Fusion Module and QM63001A diversity receive module
- Qualcomm WCD9335 Audio Codec
- Maxim MAX77854 PMIC and MAX98506BEWV audio amplifier



Galaxy S7-Edge Platform Back-Side

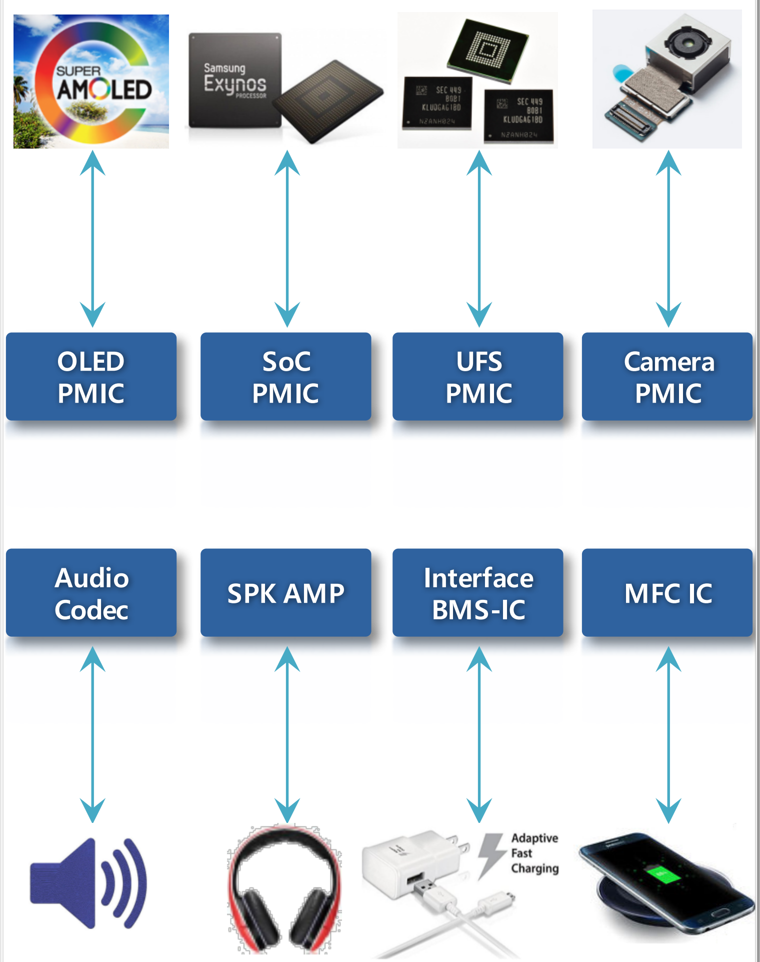
- Murata KM5D17074 Wi-Fi module
- NXP 67T05 NFC Controller
- IDT P9221 Wireless Power Reciever (likely an iteration of IDT P9220)
- Qualcomm PM8996 and PM8004 PMICs
- Qualcomm QFE3100 Envelope Tracker
- Qualcomm WTR4905 and WTR3925 RF Transceivers
- Samsung C3 image processor and Samsung S2MPB02 PMIC



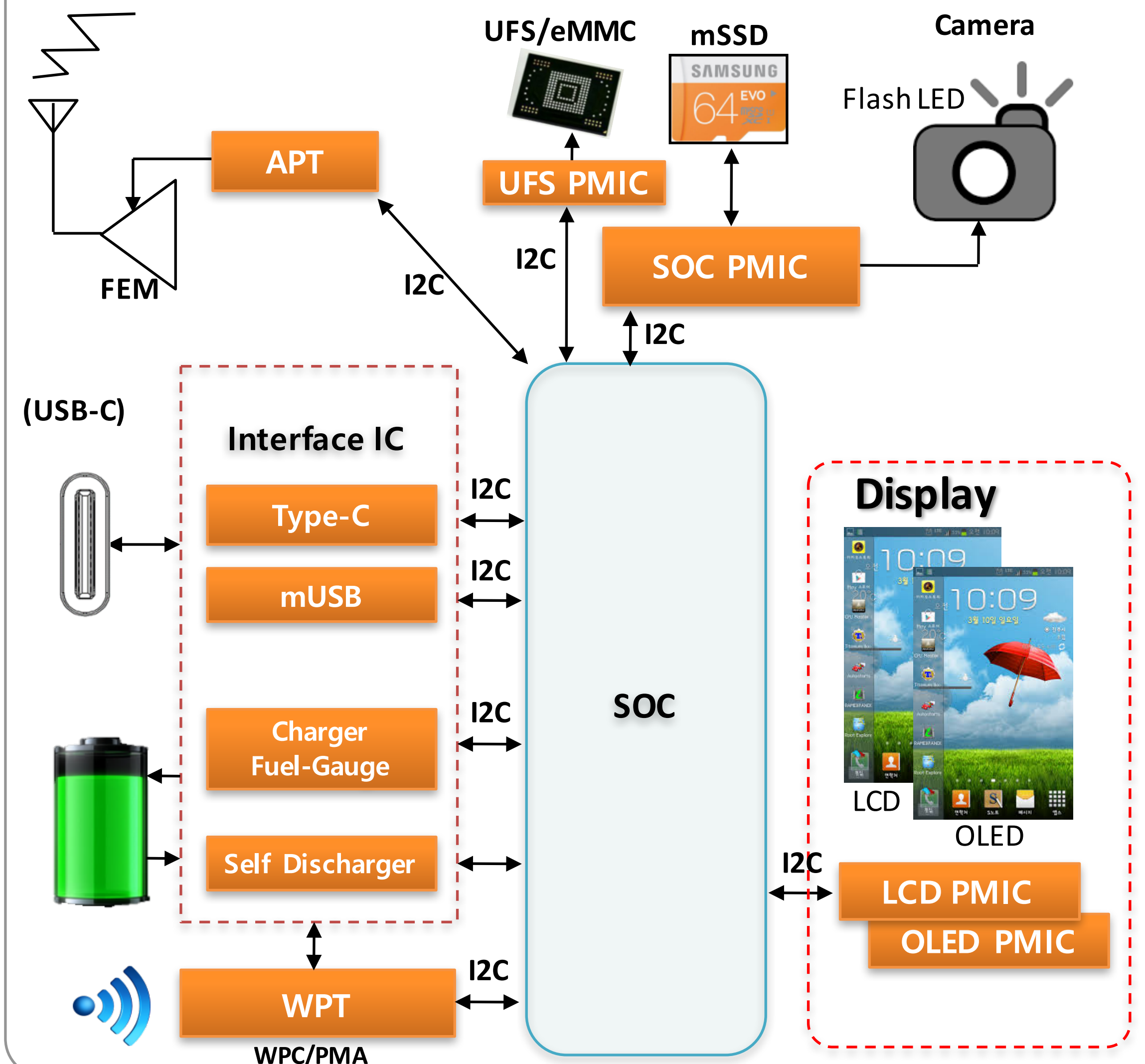
* Courtesy of iFixit

Typical Mobile Device System Power

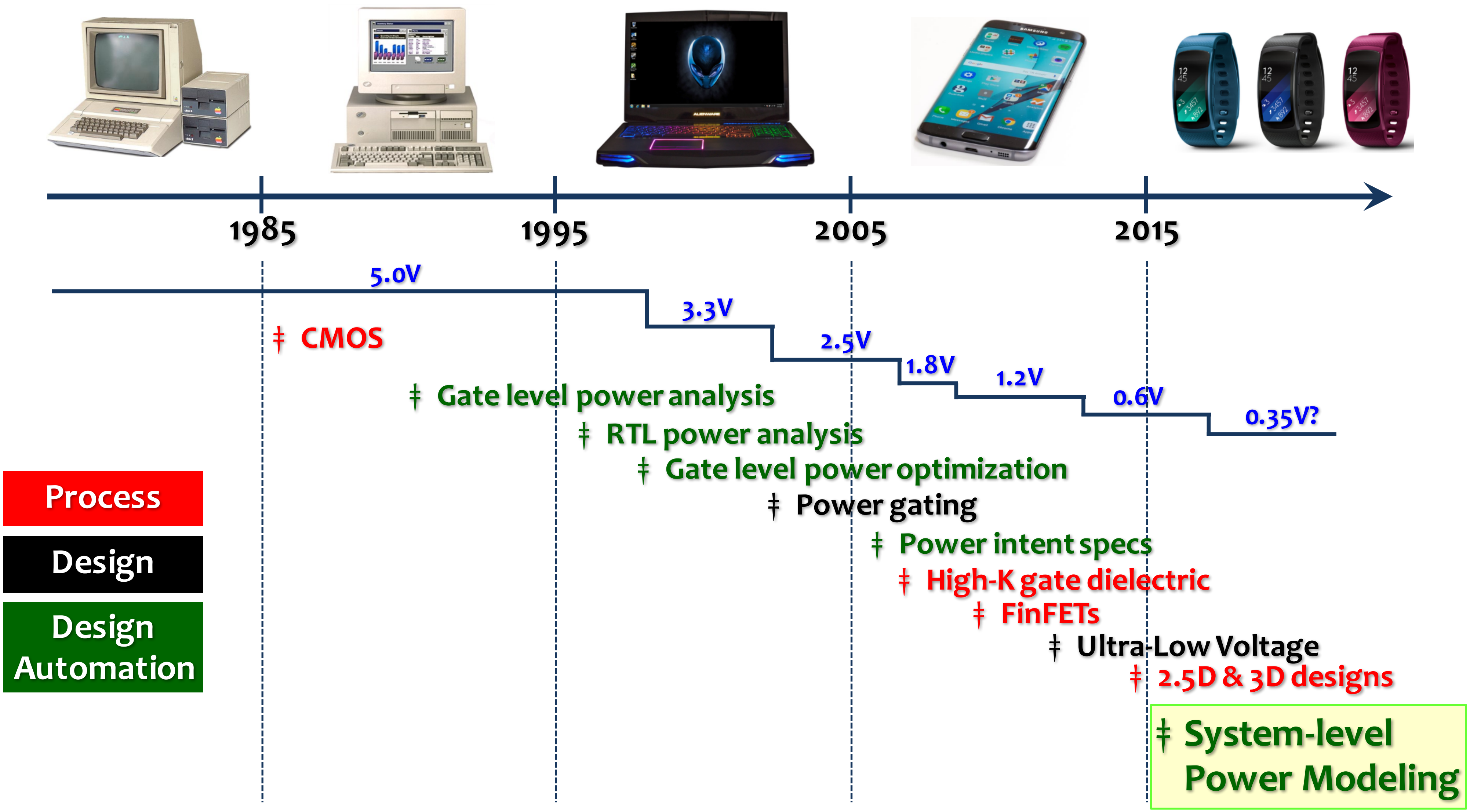
Mobile System Device Ingredients



Mobile System Power Device Connectivity



Silicon Technology Trend Setters



* Courtesy of DAC 2016

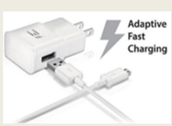
Power Delivery Requirements

Not η_{PEAK}, not even η_{MAX}, but **W-I-D-E-S-T η_{HIGH}(%) Wins!**

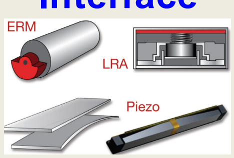
Higher Power Requirement → Complex Power Delivery and Management

Battery Charger

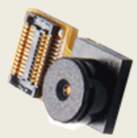
USB Interface



User Interface



CAM/SNS Power

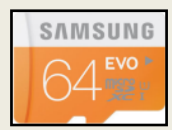


- ISP Core-DVS

Modem/RF Power

- Avg. PWR Track
- ENV. Tracking

Storage Power



- Dyn. Lane CTRL

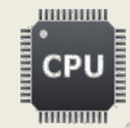
Display Power

- Panel PWR DVS
- On-Fly On/Off

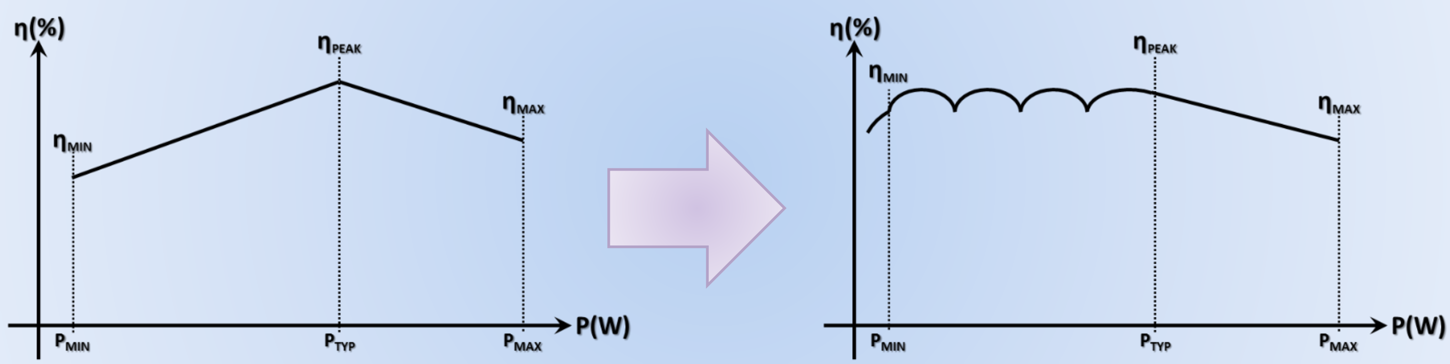
GPU Power

- DVFS
- Power Gating

CPU Power

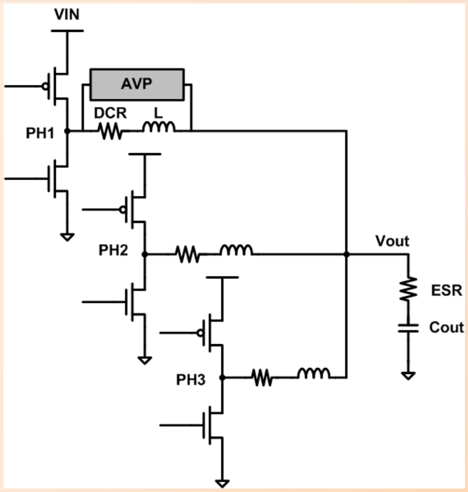


- CL-DVFS
- Power Gating
- Auto-CLK

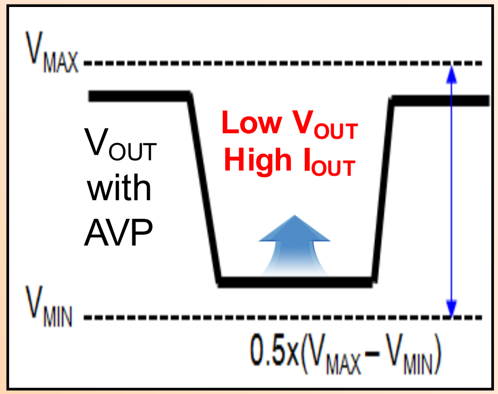


System Power Saving Techniques

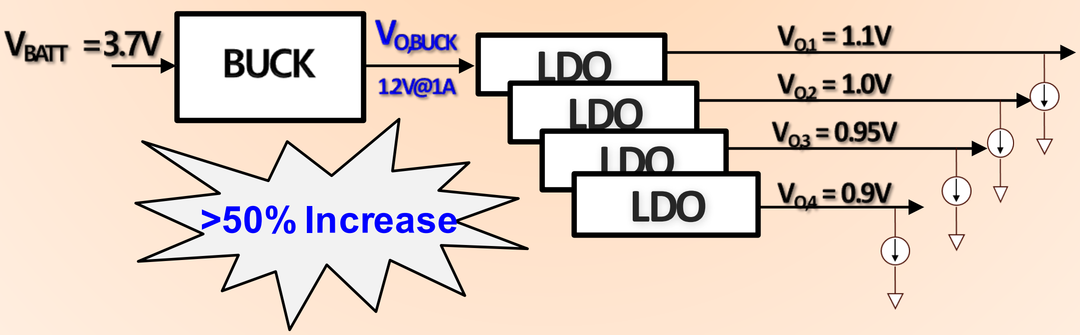
Multi-Φ BUCK



Adaptive Volt. Position



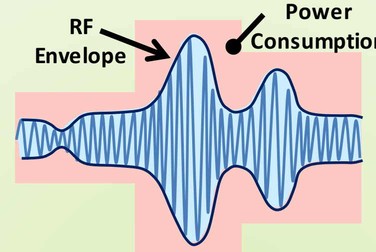
Cascaded Sub-Regulation



APT Technology

Average Power Tracking

: Discretely stepped V_{SUPPLY}

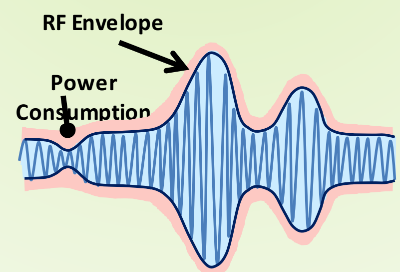


Max. P_{SAV} = 25%

ET Technology

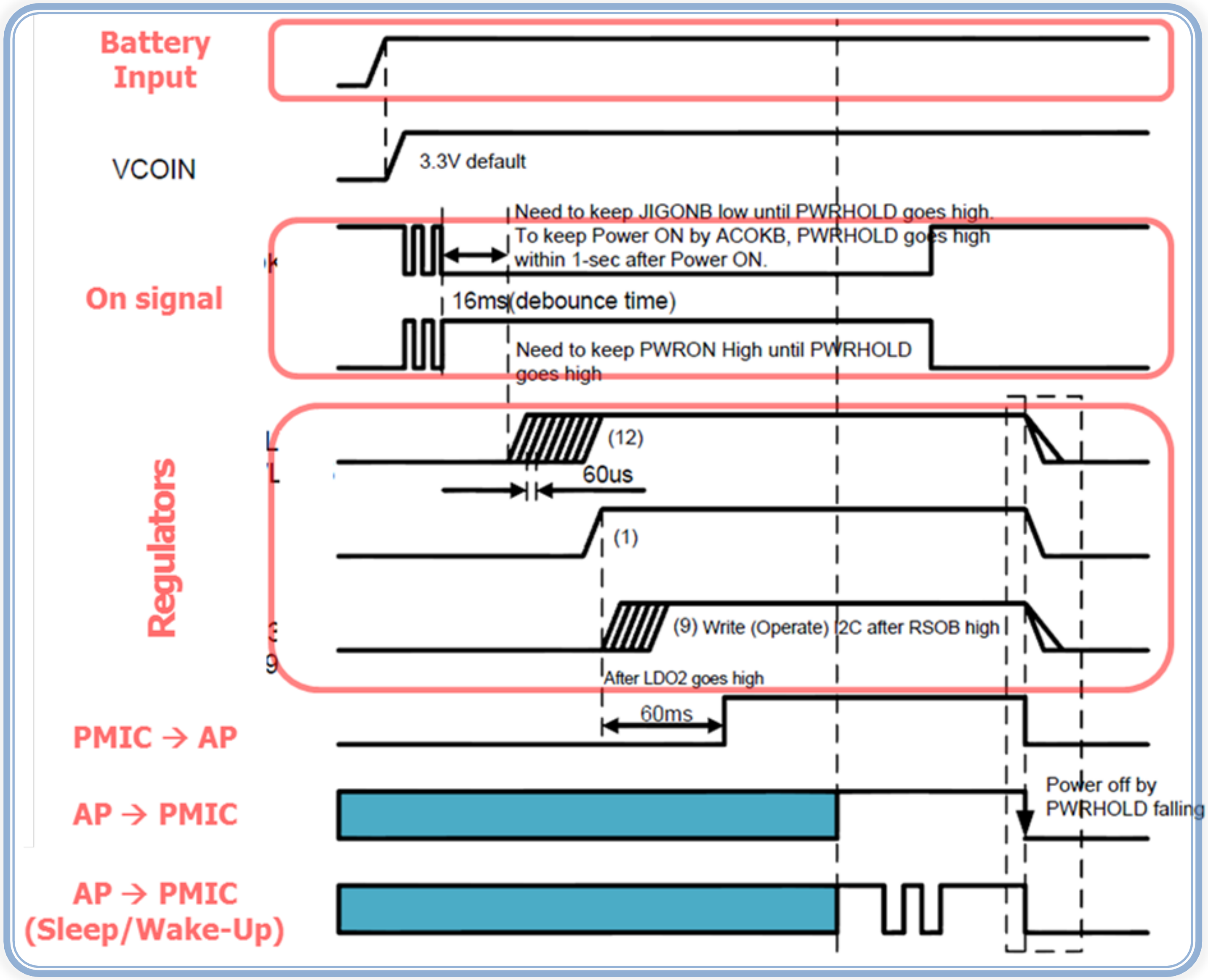
Envelope Tracking

: Conti. Modulated V_{SUPPLY}



Max. P_{SAV} = 35%

Typical Mobile SoC Power Sequencing

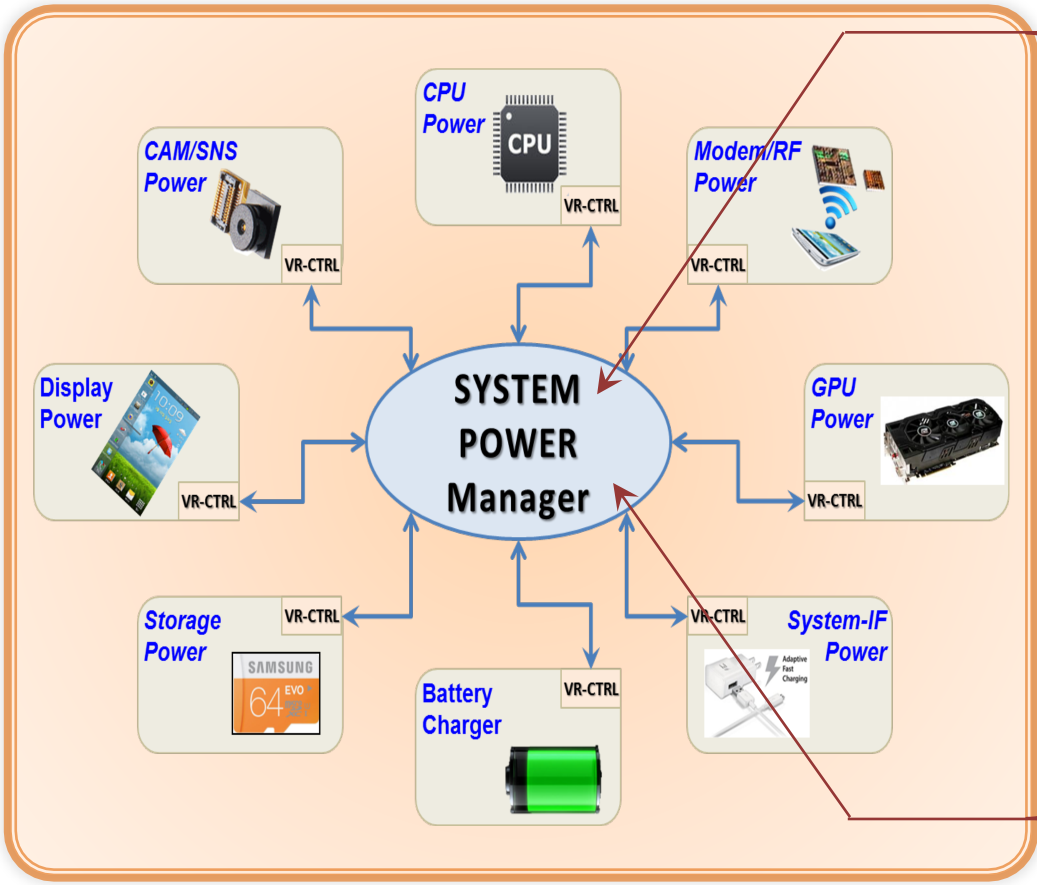


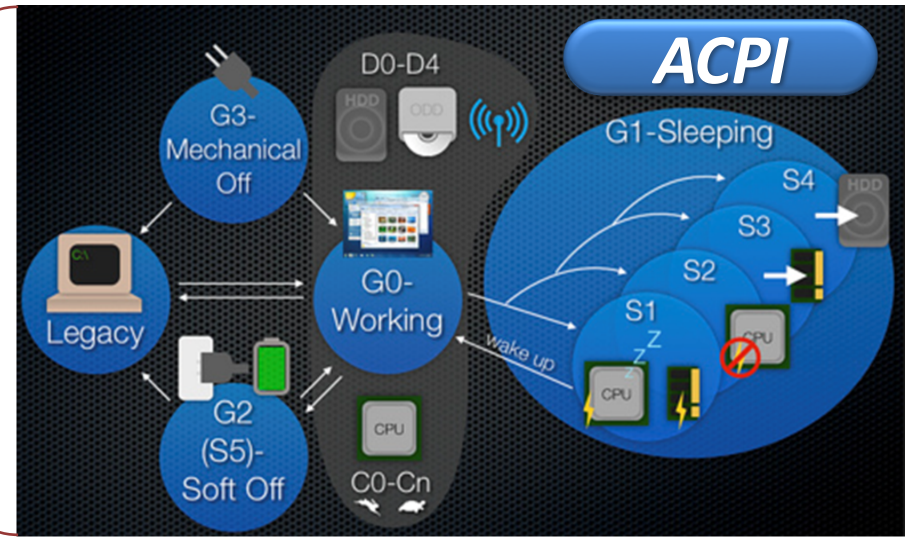
- **Input Power**
  - → 1-S Li-ion BATT
  - → V_{BUS} &/or V_{SYS}
- **PMIC Enabler**
  - → Discrete On/Off
  - → I^2C
- **VR Sequencer**
  - → Integrated SEQ
  - → By-pass via I^2C
- **PMIC COM-Link**
  - → Interrupts via I^2C

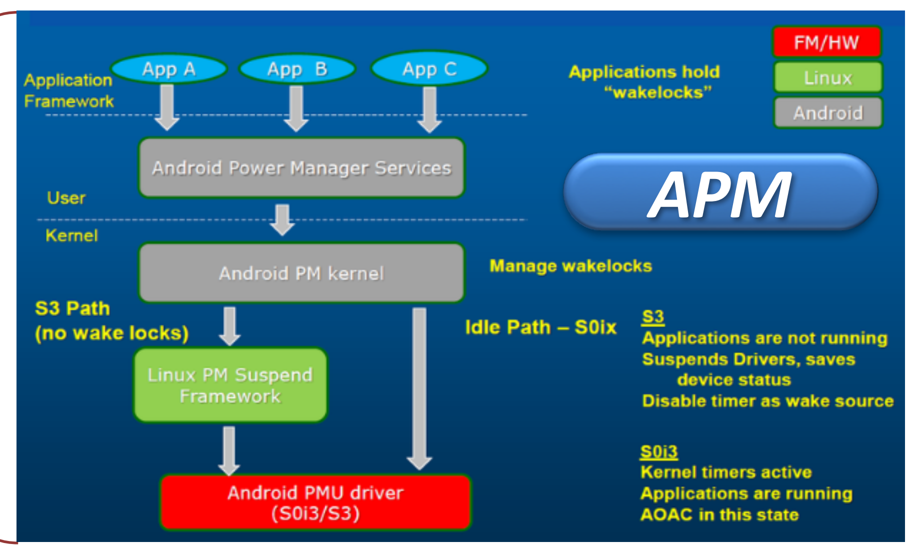
System Power Management Technology

- **THERM_THROT: Active Thermal Throttling**
  - → Skin Temperature Consideration
  - → System Thermal Throttling
  - → CPU & Device Thermal Throttling
- **SMPL: Sudden Momentarily Power Loss**
  - → Dynamic f_{CLK} Throttling to LFM for System Stability
- **P_{MAX}: Maximum Power**
- **P_{LIM}: Power Limiting**
- **ACPI: Advanced Configuration & Power Interface**
  - → G-State: G0 ~ G4 // S-State: S0 ~ S4
  - → C-State: C0 ~ C6 // P-State: P0 ~ P_n, P_m
  - → D-State: D0 ~ D4
- **APM: Android Power Management**

Mobile System Power Manager w/ ACPI & APM







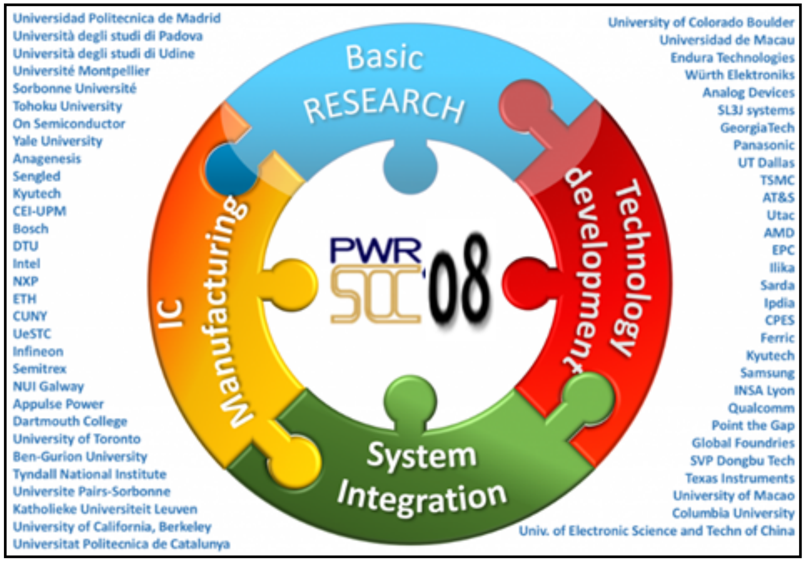
System Power Management

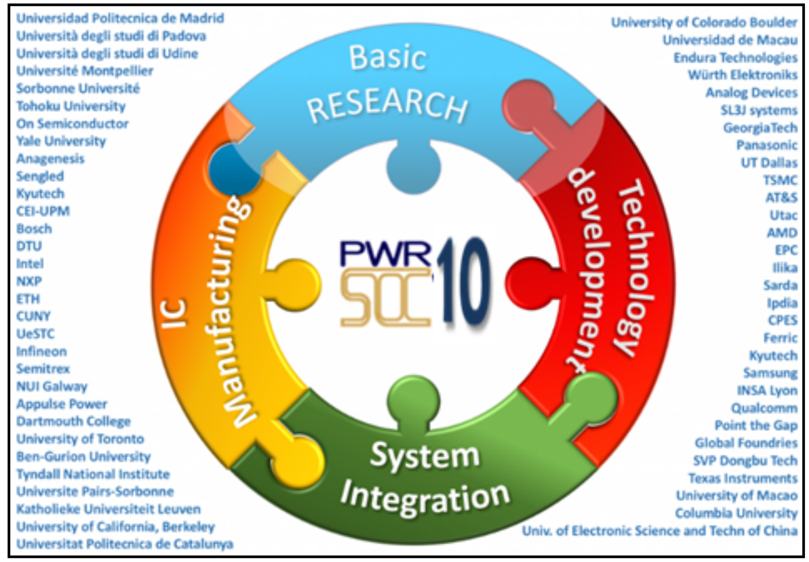
- **Mobile System Power trends increase in Complexity**
  → Expect more features/performance with longer battery life
- **Advances in System Power Delivery**
  → New advanced technologies for higher and flatter efficiency
- **System Power Management**
  → System Power Delivery must be controlled
  → Aging ACPI and APM…
- **Intelligent System Power Management???**

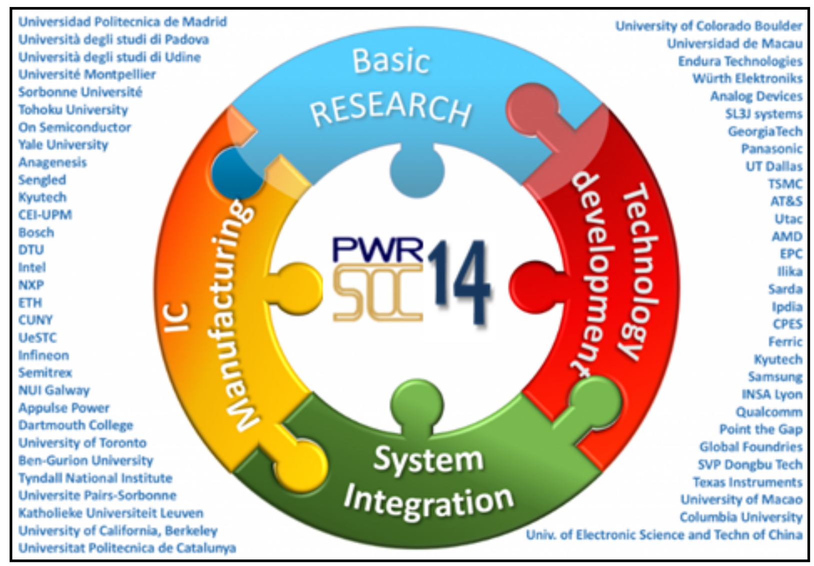
Thank you

Backup

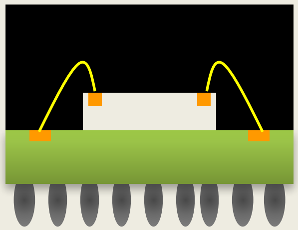
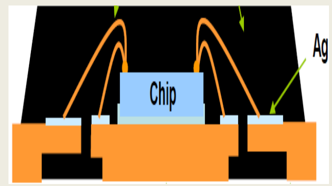
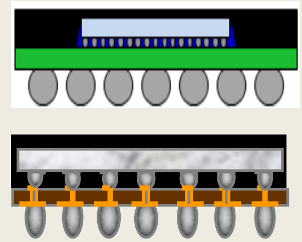
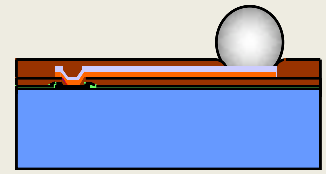
Previous PWRSoC Presentations







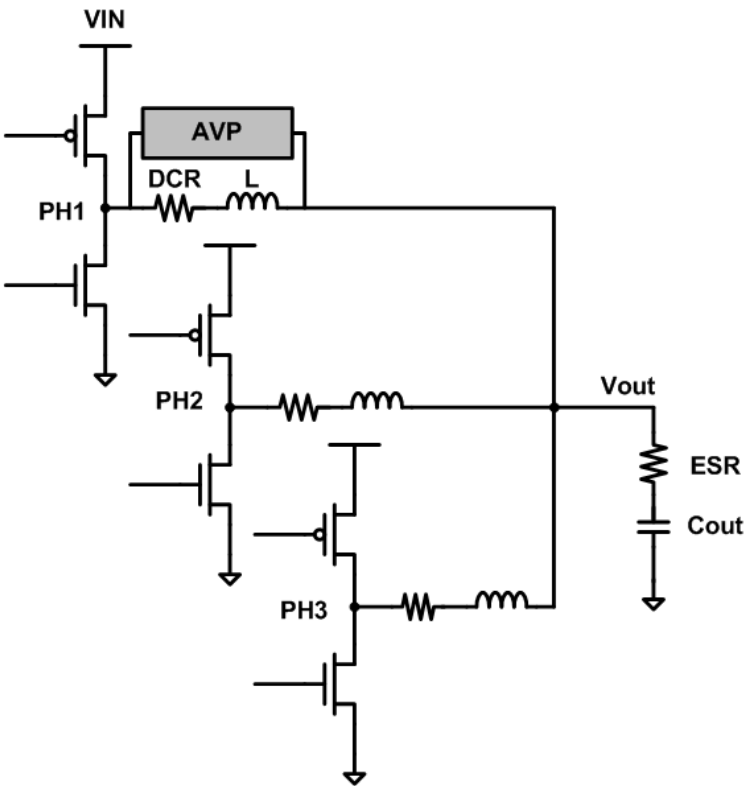
Packaging Technology

	[WB_FBGA]()	[QFN_ELP]()	[FC-FBGA (CUF/MUF mini)]()	[WLP]()
Package Solution				
PKG Cost	★★	★★	★	★★★★
Reliability	★★★★	★★★★	★★★★	★★★★
PKG size (Degree of Freedom)	★★★	★★	★★★	★★★★
Remark	. Popular Packaging Method - PKG size limit ; > $3.0x3.0mm^2$ (Die-size Independent) - Limitation of Array-type Pad configuration.	- Popular Packaging Method - Quality issue ; PKG crack Issue due to CTE Gap (LF/EMC/EPOXY) - Limitation of Array-type Pad configuration.	- Popular Packaging Method - Cost addition (PCB & Bump)	- PKG size = Chip size - Complicated Process ; WF level EDS/Test Issue (Vertical probing) Ball pitch & Chip size is estimated. Only outsource site.

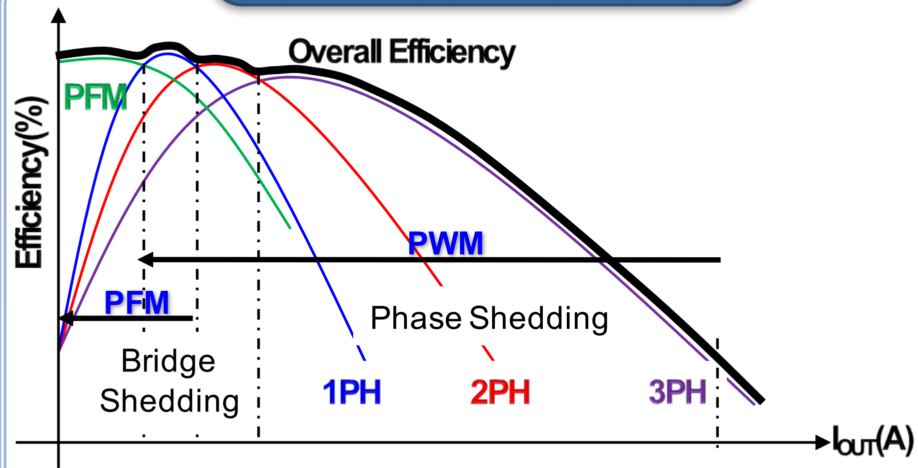
Multi-Phase SMPS for Wide Efficiency Curvature

9A, 3-Φ BUCK : $\eta(\%)_{MAX} = 89\%$

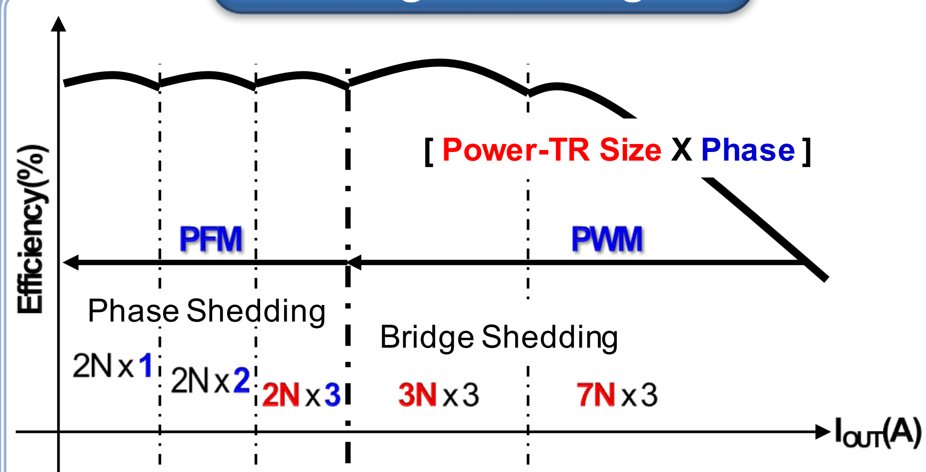
- **Conditions:**
  - V_{IN}=3.8V, V_{OUT}=0.9V
  - L=0.47uH, C_{IN}=10uF, C_{OUT}=66uF



Phase Shedding

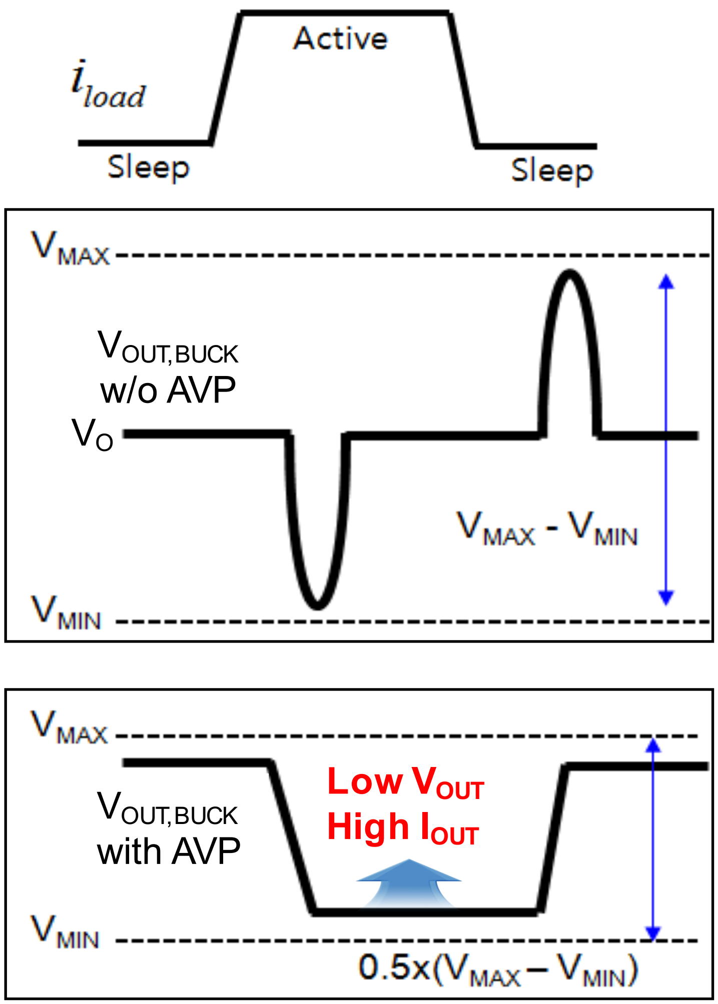


Bridge Shedding

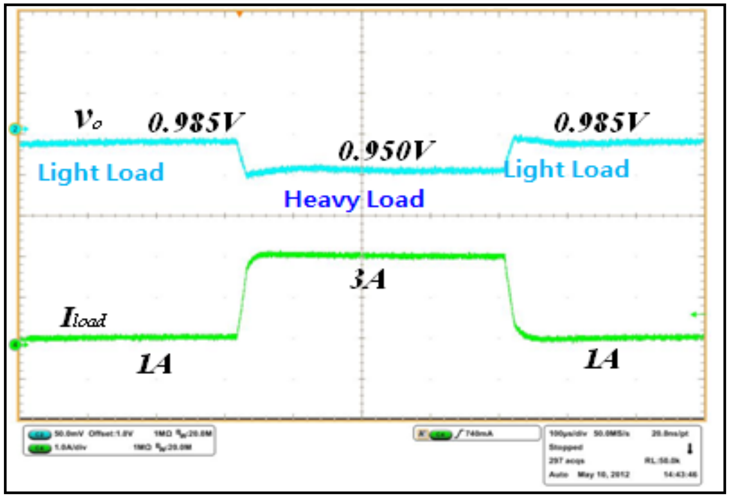


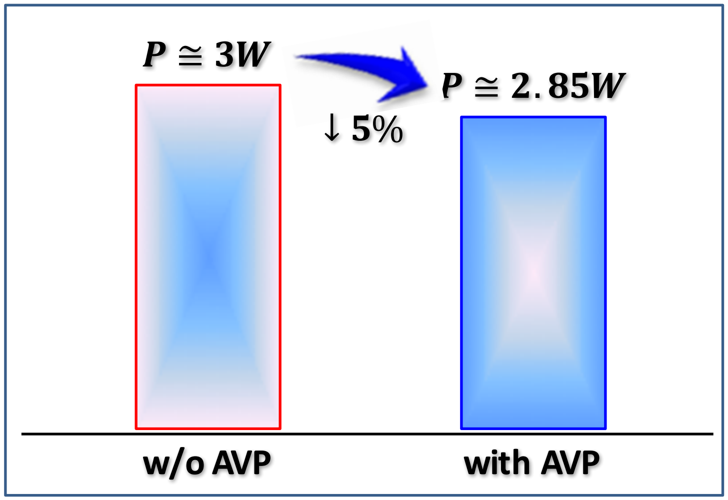
SYS_P$_{SAV}$ Technique: Adaptive Volt Positioning

AVP Explained

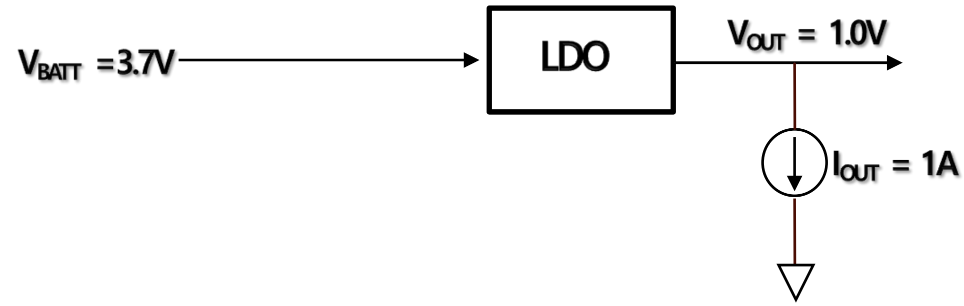
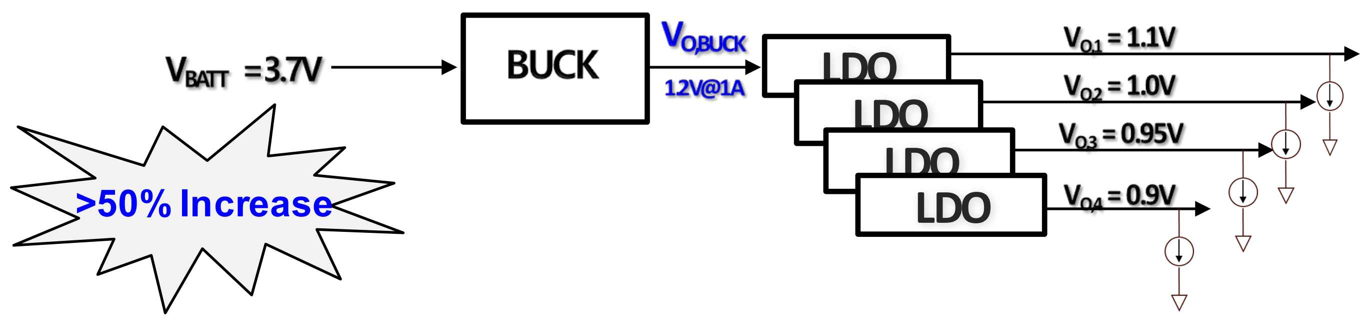
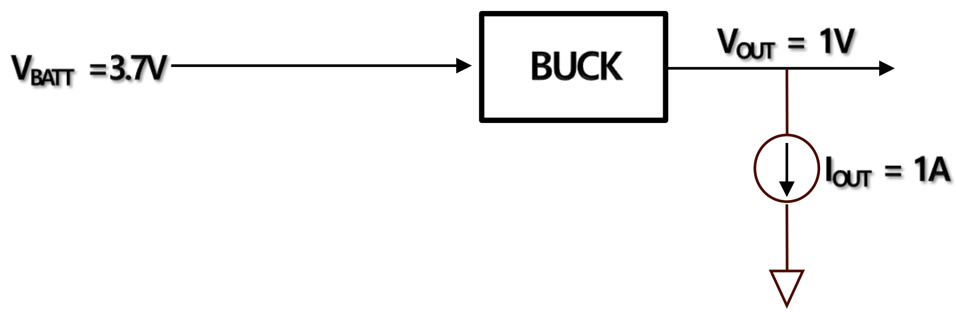


AVP Results





SYS_P_{SAV} Technique: Cascaded Sub-Regulation

Low Dropout Regulator η = 27.0%	
Cascaded Sub-REG BUCK+LDO η = 0.67~82%	
BUCK η = 90%	

SYS_P_{SAV} Technique: APT & ET for RF

APT & ET Introduction

→ PA's power consumption is at the peak during smart phone wireless transmission.

→ Average Power Tracking and/or Envelope Tracking techniques are used to increase energy efficiency.

Average Power Tracking

→ PA's supply voltage is discretely stepped in order to save power

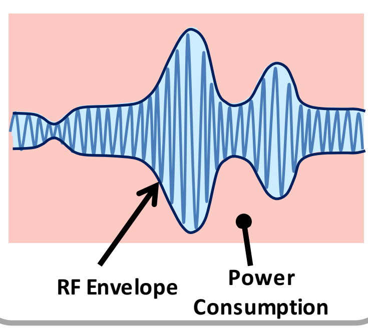
Envelope Tracking

→ PA's supply voltage is continuously modulated to match envelope to save power

Battery Supplied

Traditional PA

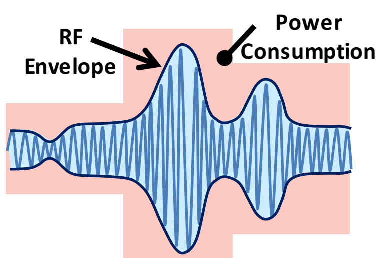
: Battery Supply Power



APT Technology

Average Power Tracking

: Discretely stepped V_{SUPPLY}

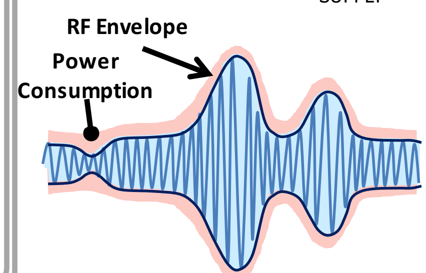


Max. P_{SAV} = 25%

ET Technology

Envelope Tracking

: Conti. Modulated V_{SUPPLY}



Max. P_{SAV} = 35%

APT-PMIC Block Diag.