AM243x OSPI PSRAM

Sitara MPU Demand Create Applications

Exported on 10/14/2024

Table of Contents

Lead customer: ABB

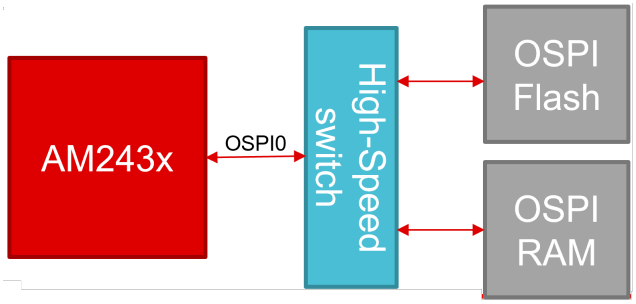
JIRA: [MCUREQ-3663] Peripheral Support: OSPI for PSRAM - Texas Instruments JIRA (ti.com)[1]

Motivation:

1. DDR is not a preferred solution due to:
    a. PCB layout & timing challenges
    b. Unpredictability
    c. Cost
2. Flash is also not a good solution due to:
    a. Less throughput (MB/s) than PSRAM
    b. Accessing flash memory devices is serial in nature.

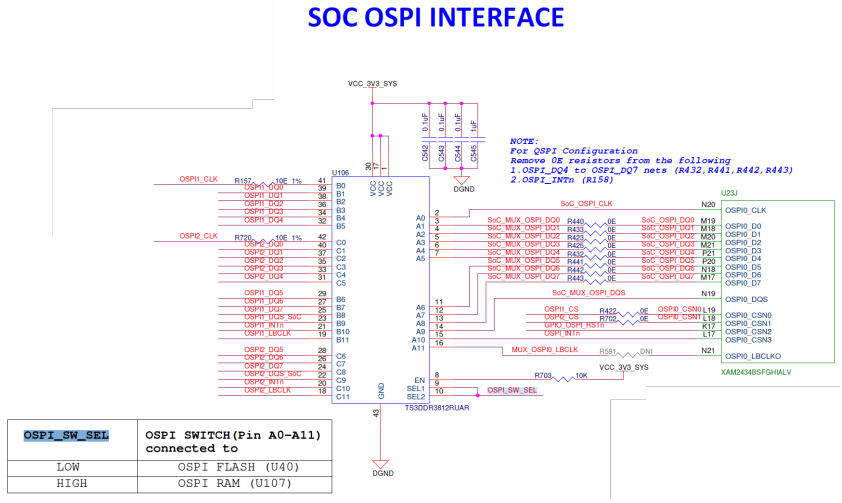
Note: related backup option is GPMC based PSRAM MCUREQ-295 Tanmay Deshpande (looks like no Confluence ID ?) is working on this.

EVM Modification Schematic:



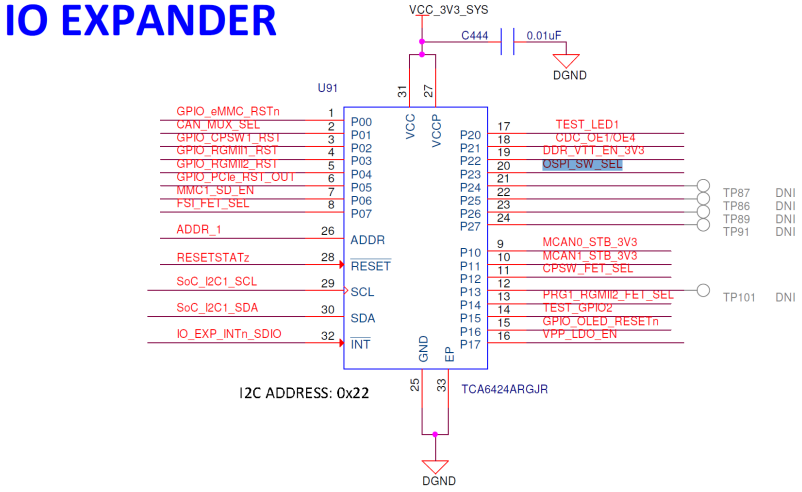
PROC101E1_OSPI_SCH_AM243x.pdf[2]

High Speed Switch:



IO Expander used to set OSPI_SW_SEL:

1 https://jira.itg.ti.com/browse/MCUREQ-3663
2 https://confluence.itg.ti.com/download/attachments/946946418/PROC101E1_OSPI_SCH_AM243x.pdf?api=v2&modificationDate=1712771067000&version=1



Note: There is a 10K pull-down on OSPI_SW_SEL to default to OSPI FLASH

PSRAM datasheet:

APM_PSRAM_OPI_Xccela_APS6408L_3OBMx_v3_5b_PKG-1954852.pdf[3]

SOFTWARE:

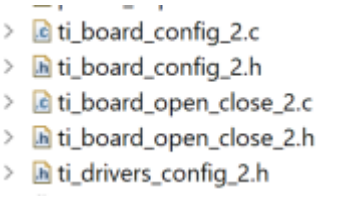
- Created MCU-SDK: CCS project Skeleton AM243x OSPI PSRAM
  - ospi_psram_io_am243x-lp_r5fss0-0_nortos_ti-arm-clang
    - Added PSRAM to board lib (don't forget to rebuild lib)
      - C:\ti\mcu_plus_sdk_am243x_09_01_00_41\source\board\makefile.am243x.r5f.ti-arm-clang

```
LIBNAME:=board.am243x.r5f.ti-arm-clang.$(PROFILE).lib

FILES_common := \
    eeprom.c \
    eeprom_at24c.c \
    ethphy.c \
    ethphy_dp83869.c \
    flash.c \
    flash_nand_gpmc.c \
    flash_nor_ospi.c \
    led.c \
    led_gpio.c \
    led_tpic2810.c \
    led_ioexp.c \
    ioexp_tca6424.c \
    nor_spi_sfdp.c \
    psram.c \
    psram_gpmc.c \

FILES_PATH_common = \
    eeprom \
    ethphy \
    flash \
    flash/gpmc \
    flash/sfdp \
    flash/ospi \
    led \
    ioexp \
    psram \
    psram/gpmc \
```

3 https://confluence.itg.ti.com/download/attachments/946946418/APM_PSRAM_OPI_Xccela_APS6408L_3OBMx_v3_5b_PKG-1954852.pdf?api=v2&modificationDate=1712891858000&version=1

- Libs rebuild ex:
    - cd C:\ti\mcu_plus_sdk_am243x_09_02_00_50
    - gmake libs PROFILE=debug
    - Don't forget to update CCS version and other tools in imports.mak
- Fix for undeclared NULL error. Add in psram.c
    - #include <stddef.h

- Taking care of redundancies from SysConfig by adding additional ti_board* and ti_drivers* files



- Sysconfig
    - I2C1 instance used.
    - Other params as default
- Added "io_expander.c" to CCS project to configure IO expander by using TCA6424 APIs (ioexp_tca6424.h).
    - Used TCA6424_Params_init() which sets I2C address to 0x22
    - "ioIndex=19" which correspond to Pin23 (20)→ OSPI_SW_SEL.
        - LOW → OSPI FLASH
        - HIGH → OSPI_RAM
- Added header file for PSRAM configuration (aps6408.h)
- Added "psram_ospi.c"
    - Implemented functions to read Device ID / Manufacture ID
        - Underneath OSPI APIs are called (ex: OSPI_readCmd())
    - Implemented Psram_ospiRead(), Psram_ospiWrite(), Psram_ospiOpen(), Psram_ospiClose()
        - These functions call:
            - OSPI_Transaction_init(), OSPI_readDirect(), OSPI_writeDirect(), OSPI_getHandle(), OSPI_enablePhy(), and OSPI_disablePhy()
- **ToDo:** Need to confirm if APP_OSPI_PSRAM_OFFSET_BASE can be 0x0

PROPOSED TEST

1. OSPI Flash a "Hello world" and confirm new board works OK
2. Flash "ospi_psram_io_am243x-lp_r5fss0-0_nortos_ti-arm-clang.out" and check if there is any error

a. Can it boot?
b. Can we correctly print DeviceID?. This will ensure basic communication is OK
    i. If not correct DeviceID read, then change (increase) RD delay (OSPI_setRdDataCaptureDelay())

3. If 2. works, then we can run "ospi_psram_io_main()" instead of "ospi_psram_basic_init_main()".
    a. "ospi_psram_io_main" fills a buffer, then write it to PSRAM and read it back to compare. If comparison is OK, then prints "All tests have passed!!"

CODE UPDATES (based on AM261 SoC verification test)

- OSPI configuration:
    - From APS6808L datasheet we have:
        - Interface: Octal SPI with DDR Xccela mode.
        - Only 8D-8D-8D supported
    - Other params:
        - Address 4bytes
        - Read dummy cycles 7 (should be 6, but for AVV test 7 was needed)
        - For simplicity, poll and PHY disabled
        - Clk 192MHz, DIV=8
        - OSPI read/write direct (DAC enabled)
        - Initial test will use memcpy, no DMA
- PSRAM configuration
    - Configuring for Fixed Latency, using Write Latency Code of 4Cycles (109Mhz from datasheet), and 16Byte Burst length
    - Read and Write: Linear Burst

CODE - DRAFT (untested)

Unzip below inside C:\ti\mcu_plus_sdk_am243x_09_01_00_41\examples\drivers\ospi

ospi_psram_io.zip[4]

Unzip below inside C:\ti\mcu_plus_sdk_am243x_09_02_00_50\examples\drivers\ospi

ospi_psram_io_v2.zip[5]

SoC Verification setup for AM261: APM SRAM TEST.zip[6]

BOARD BRING UP (08/2024)

- **SBL OSPI Test**

4 https://confluence.itg.ti.com/download/attachments/946946418/ospi_psram_io.zip?api=v2&modificationDate=1713389005000&version=2
5 https://confluence.itg.ti.com/download/attachments/946946418/ospi_psram_io_v2.zip?api=v2&modificationDate=1715880135000&version=1
6 https://confluence.itg.ti.com/download/attachments/946946418/APM%20SRAM%20TEST.zip?api=v2&modificationDate=1715880345000&version=1

- Flash/Run "hello_world", "ospi_flash_io", and "ospi_psram_io" tests: PASS with below workarounds
    - UART Uniflash modifications, to fix "magic number error":
        - In SysConfig Memory regions changed **.bss.filebuf** location from DDR to a new added MSRAM2
        - Changed **BOOTLOADER_UNIFLASH_MAX_FILE_SIZE** to **0x60000** in main.c to match the size of MSRAM_2 section in linker.cmd
    - OSPI known issues for AM243x EVM: [MCUSDK-12960] DAC is not enabled before Bootloader_getMsgLen leading to data abort - Texas Instruments JIRA (ti.com)[7]
        - Workarounds
            - sbl_ospi_am243x-evm_r5fss0-0_nortos_ti-arm-clang:
                - In SysConfig: OSPI keeps "PHY enabled mode"
                - In SysConfig: BOOTLOADER select "Disable Auth Application Image"
                - in main.c: DAC mode enabled before Bootloader_parseMultiCoreAppImage() workaround
                    - OSPI_Handle ospi_handle = OSPI_getHandle(CONFIG_OSPI0);
                      OSPI_enableDacMode(ospi_handle);
                      status = Bootloader_parseMultiCoreAppImage(bootHandle, &bootImageInfo);
- Unzip below inside C:\ti\mcu_plus_sdk_am243x_09_02_00_50\examples\drivers\ospi
    - ospi_psram_io_v3_mistral_changes.zip[8]
    - Additional OSPI's driver changes: ospi_v0.c[9]
        - Don't forget rebuild libs
            - cd C:\ti\mcu_plus_sdk_am243x_09_02_00_50
            - gmake libs PROFILE=debug
- Results:
    - [BOOTLOADER_PROFILE] Boot Media : NOR SPI FLASH
      KPI_DATA: [BOOTLOADER_PROFILE] Boot Media Clock : 166.667 MHz
      KPI_DATA: [BOOTLOADER_PROFILE] Boot Image Size : 0 KB
      [BOOTLOADER_PROFILE] Cores present :
      r5f0-0
      KPI_DATA: [BOOTLOADER PROFILE] SYSFW init : 11802us

7 https://jira.itg.ti.com/browse/MCUSDK-12960
8 https://confluence.itg.ti.com/download/attachments/946946418/ospi_psram_io_v3_mistral_changes.zip?api=v2&modificationDate=1724084170000&version=1
9 https://confluence.itg.ti.com/download/attachments/946946418/ospi_v0.c?api=v2&modificationDate=1724084259000&version=1

```
KPI_DATA: [BOOTLOADER PROFILE] System_init                  :    364869us
KPI_DATA: [BOOTLOADER PROFILE] Drivers_open                 :       89us
KPI_DATA: [BOOTLOADER PROFILE] Board_driversOpen            :   2523463us
KPI_DATA: [BOOTLOADER PROFILE] Sciclient Get Version        :     13928us
KPI_DATA: [BOOTLOADER PROFILE] CPU load                     :    64385us
KPI_DATA: [BOOTLOADER_PROFILE] SBL Total Time Taken         :   2985155us

Image loading done, switching to application ...
before SemaphoreP_pend ...
After SemaphoreP_pend ...
before I2C_transfer  ...
after I2C_transfer  ...
PSRAM Manufacturer ID : 0xD
PSRAM Device ID: 0x2
All tests have passed!!
```

OSPI PSRAM test:

- **PSRAM WR/RD.** Below combinations tested OK for 4KBytes
- WRITE=INDAC; READ=DAC
- WRITE=DAC; READ= DAC
- WRITE=INDAC; READ=INDAC
- **Latency / BW Benchmark:** Currently in progress