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Micron

A Systematic IP Verification Solution of Complex Memory Management for Storage SOC

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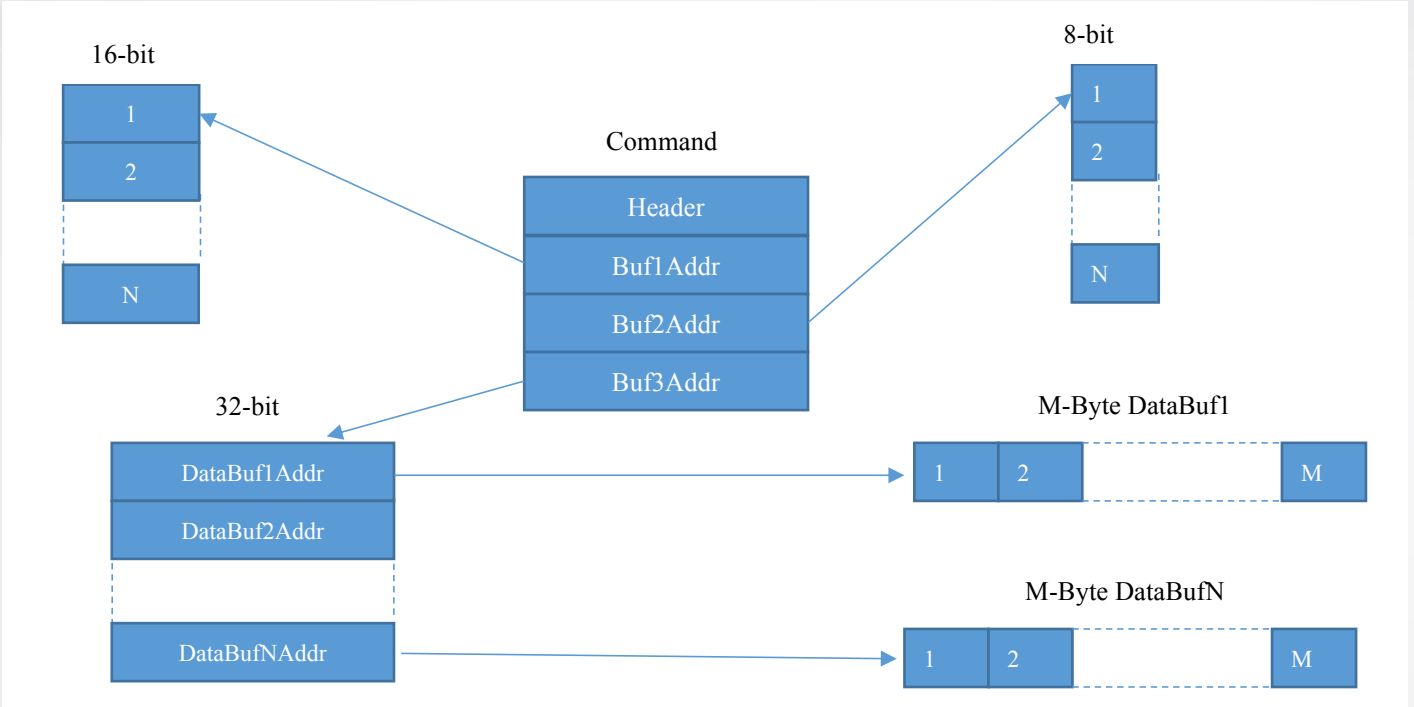
Data Struct Requirement



- Alignment – 8/16/32/64/128-bit aligned.
- Entry Width – 8/16/32/64/128-bit or User-defined transaction.
- Size – User-defined.
- Locality – Nearby/Broad.

Features and Benefits

- ✓ Provide system memories modeling for complex SOC.
- ✓ Address mapping of system memories can be configurable.
- ✓ Support different SOC buses like APB, AHB, AXI or other internal system bus.
- ✓ Allocate memory with different requirements of alignment / width / size / locality / mode.
- ✓ Load and store user-defined transaction.
- ✓ Collect functional coverage to make sure all legal memory regions are fully covered.
- ✓ Support debug mode. Allocation and deallocation, load and store operations can be dumped.

uvm_mem_mam Extension

uvm_mem_mam supports:

- Allocation Alignment – Byte aligned.
- Allocation Mode – Thrifty.
- Allocation Locality – Nearby.
- Read and Write – Data struct: uvm_reg_data

Extension from uvm_mem_mam:

- ✓ Allocation Alignment – 8/16/32/64/128-bit aligned.
- ✓ Allocation Mode – Thrifty and Greedy.
- ✓ Allocation Locality -- Nearby and Broad.
- ✓ Read and Write – Data struct: User-defined transaction and 8/16/32/64/128-bit entry width.

Implementation – Configuration I

Memory Manager Configuration API

API Prototyping	Descriptions
bit configure (smm_cfg cfg_p)	Configure system memory manager, this API is usually called initially after the environment has been built. (For example, call the API in connect_phase() in IP environment.)

Memory Manager Configuration Data Struct

Field	Descriptions
start_offset	The start address of system memory address space that is to be allocated.
end_offset	The end address of system memory address space that is to be allocated.
alloc_mode	Allocation mode, by default this field is randomized between the below modes: GREEDY: Allocate un-allocated memory region with priority. THRIFTY: Allocate just released memory region with priority.
locality	Locality for memory allocation, by default this field is randomized between the below modes: BROAD: Randomly allocate regions throughout system memory. NEARBY: Allocate regions adjacent to allocated regions with priority.

Implementation – Configuration II

Example: Memory Manager Configuration

```
function void connect_phase(uvm_phase phase);
  smm_cfg cfg_v;
  system_mem_manager smm;

  super.connect_phase(phase);
  //Create a singleton memory manager.
  smm = system_mem_manager::get();

  //Configure address space for system memory.
  cfg_v = smm_cfg::type_id::create("cfg_v");
  cfg_v.randomize() with {start_offset== 32'h0000_0000;
                          end_offset = 32'hFFFF_FFFF;};
  smm.configure(cfg_v);

  //Pass shadow memory to memory manger.
  smm.mem_h = mbp_slave_agent[0].slave_mem;

endfunction
```

Implementation – Allocation/Deallocation I

Memory Allocation/Deallocation APIs

API Prototyping	Descriptions
bit alloc_mem (input int byte_size, input mem_manager_policy policy, output bit[31:0] start_addr)	Allocate memory segments with the specified size and policy (alignment, allocation strategy and etc.), and the returned start_addr is the starting address of the allocated memory. Return 0 for failures
bit dealloc_mem (input bit[31:0] start_addr)	De-allocate memory segments which have been allocated before. Note that the start address should be the same as that of the corresponding alloc_mem function and all the allocated memory segment will be released. Return 0 for failures
bit reserve_mem (input int byte_size,input[31:0] start_addr)	Allocate one memory segment with specified size and starting address. The memory segment can't be allocated unless it is released. This API can also be used to pre-allocate some memory regions initially which can't be allocated. For example, address maps for block registers need to be reserved. Return 0 for failures. (i.e. The memory segment has been allocated before)

Implementation – Allocation/Deallocation II

Memory Allocation Policy Data Struct

Field	Descriptions
alloc_min_offset	Specify the minimum memory offset that can be allocated. This field and the below alloc_max_offset can be used to define a sub-region to be allocated.
alloc_max_offset	Specify the maximum memory offset that can be allocated.
addr_align	Allocation address alignment: BYTE_ALIGN: allocated address should be byte aligned WORD_ALIGN: allocated address should be 2-byte aligned DWORD_ALIGN: allocated address should be 4-byte aligned QWORD_ALIGN: allocated address should be 8-byte aligned EWORD_ALIGN: allocated address should be 16-byte aligned

Implementation – Allocation/Deallocation III

Example: Memory Allocation/Deallocation

```
task body();
  system_mem_manager smm;
  mem_manager_policy mmp;
  bit [31:0] addr;

  mmp = new();
  smm = system_memory_manager::get();

  mmp.addr_align = SMM_BYTE_ALIGN;
  mmp.alloc_min_offset = 32'hFFF3_0000;
  mmp.alloc_max_offset = 32'hFFF3_F000;
  assert (smm.alloc_mem(4096, mmp, addr);
  `uvm_info(get_name(), $sformatf("Allocated addr=0x%0h", addr), UVM_LOW)

  smm.dealloc_mem(addr);
  `uvm_info(get_name(), $sformatf("De-allocate addr=0x%0h", addr), UVM_LOW)
endtask
```

Example: Memory Reservation

```
function reserve_csr_mem_region();
  smm.reserve_mem(CSR_MEM_SIZE, CSR_BASE_ADDR);
endfunction
```

Implementation – Load and Store APIs I

Load and Store User-defined Transaction

API Prototyping	Descriptions
bit store_usr_data(input bit[31:0] start_addr, input base_usr_data usr_data)	Backdoor store data with user-defined format (extended from base_usr_data) into specified memory address. Return 0 for failures
bit load_usr_data(input bit[31:0] start_addr, inout base_usr_data usr_data)	Backdoor load data with user-defined format (extended from base_usr_data) from specified memory address Return 0 for failures

Virtual Function in Base Class of User-defined

Virtual Function	Descriptions
int get_byte_size();	This function must be extended in child classes to define the byte size of user defined data.
void unpack_bytes(input bit[7:0] byte_in[]);	This function must be extended in child classes to convert input byte array into user-defined data. The input byte array size should match what is defined in the above get_byte_size() function. This function will be called by load_usr_data API.
void pack_bytes(output bit[7:0] bytes_out[]);	This function must be extended in child classes to convert user-defined data into byte array. The byte array size is also defined in the above get_byte_size() function. This function will be called by store_usr_data API.

Implementation – Load and Store APIs II

Example: User-defined Transaction Extends From Base_User_Data

```
class dec_bufferlist_txn extends base_usr_data;

  rand Dec_BufferList_DW0 dw0;
  rand Dec_BufferList_DW1 dw1;

  `uvm_object_utils_begin(dec_bufferlist_txn)
    `uvm_field_int(dw0,         UVM_ALL_ON);
    `uvm_field_int(dw1,         UVM_ALL_ON);
  `uvm_object_utils_end

  function new(string name = "dec_bufferlist_txn");
    super.new(name);
  endfunction

  // This function is mandatory to be implemented to specify the byte size of
this txn.
  function int get_byte_size();
     return 8;
  endfunction
```

```
//This function will be called by load_usr_data().
  function void unpack_bytes(input bit[7:0] byte_in[]);
   assert(byte_in.size() == get_byte_size()); //check input array size
   dw0={byte_in[3], byte_in[2], byte_in[1], byte_in[0]};
    dw1={byte_in[7], byte_in[6], byte_in[5], byte_in[4]};
  endfunction

  //This function will be called by store_usr_data().
  function void pack_bytes(output bit[7:0] bytes_out[]);
   bytes_out = new[get_byte_size()]; //create an array with expected size.
   {bytes_out[3], bytes_out[2], bytes_out[1], bytes_out[0]} = dw0;
    {bytes_out[7], bytes_out[6], bytes_out[5], bytes_out[4]} = dw1;
  endfunction

  function string convert2string();
    string s;
    s = { s, $sformatf("dw0: %p\n", dw0      ) };
    s = { s, $sformatf("dw1: %p\n", dw1      ) };
    return s;
  endfunction
endclass
```

Implementation – Load and Store APIs III

Example: Store User-defined Transaction

```
rand dec_bufferlist_txn buf_h;
bit [31:0] cwl_addr = 0;
bit suc;

buf_h = new();
if (!buf_h.randomize())  `uvm_error(get_name(), "buf_h randomization failed")

suc = smm.store_usr_data(cwl_addr, buf_h);
if (suc == 0) `uvm_error(get_name(), "store buf_h failed")
```

Implementation – Load and Store APIs IV

Example: Load User-defined Transaction

```
function dec_bufferlist_txn load_buf_list(bit [31:0] addr);
  bit suc;
  base_usr_data    base_usr_data_h;
  dec_bufferlist_txn buf_h;

  buf_h = new();

  //It is mandatory to pass a handle with “base_usr_data” type instead of its
  extended type as the 2nd argument of load_usr_data().
  //It is recommended to $cast the extended item to a “base_usr_data” handle
  and pass it to the load_usr_data() function. After calling load_usr_data(),
  $cast the “base_usr_data” handle back to the extended item.
  if (!$cast(base_usr_data_h, buf_h))
    `uvm_error(get_name(), "child entity cast to parent handle failed.")
```

```
  suc = smm.load_usr_data(addr, base_usr_data_h);

  if (!$cast(buf_h, base_usr_data_h))
    `uvm_error(get_name(), "parent handle cast to child entity failed.")

  if (suc == 0)
    `uvm_error(get_name(), "load_usr_data failed")

  return buf_h;
endfunction
```