AN1069
APPLICATION NOTE

ADDRESSING UP TO 4 MBYTES OF MEMORY FROM A ST9+ WITH A 16-BIT EXTERNAL BUS

By Microcontroller Division Applications

INTRODUCTION

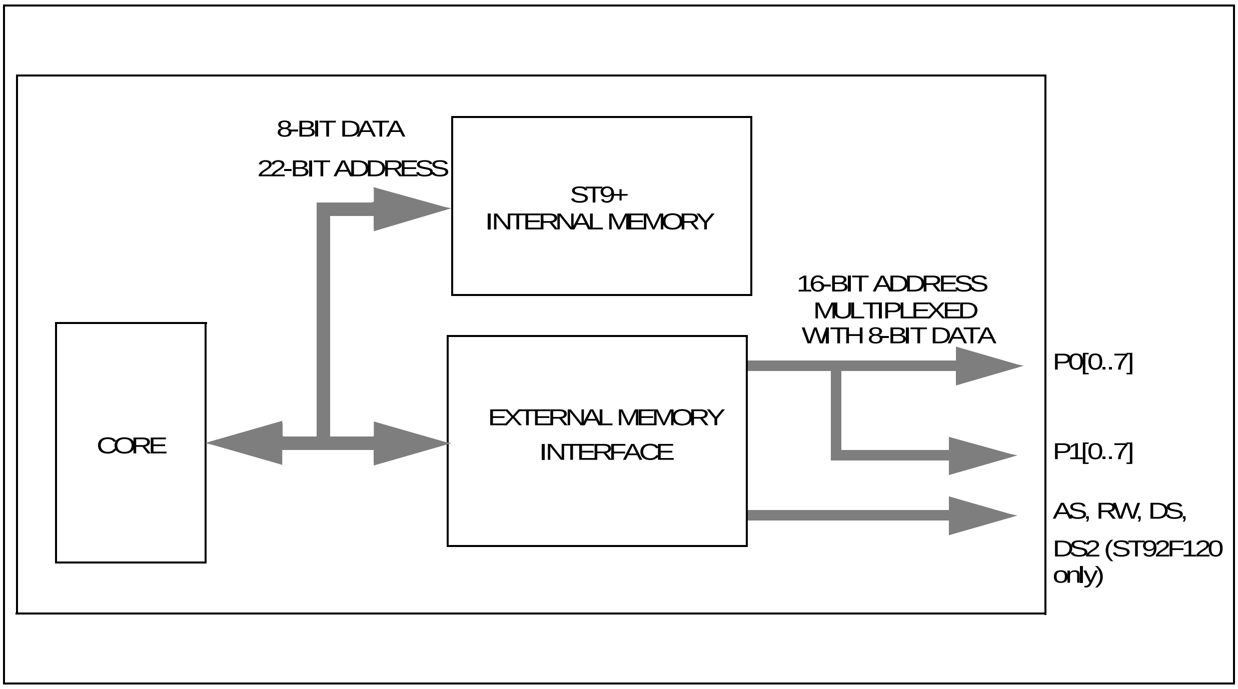
This application note is to help developers of ST9+ applications that need to address external memory. It refers to ST9+ microcontrollers which have only a 16-bit external address bus (such as the ST90158). The information in this application note does not apply to ST9+ microcontrollers that have a 22-bit external address bus.

1 ST9 EXTERNAL MEMORY MANAGEMENT

Through the Memory Management Unit (MMU), ST9+ devices can internally address up to 4M bytes of linear memory using a 22-bit address bus (refer to the datasheet or ST9+ user guide for more information on the MMU).

Nevertheless, most general purpose ST9+ microcontrollers do not output this 22-bit address bus, they only output the 16 Least Significant Bits (LSBs) of the 22-bit address. This 16-bit address is output on two 8-bit ports: P0 and P1. This allows the user to address 64 Kbytes (2^{16}) of external memory directly.

Figure 1. ST9+ Memory Access Overview

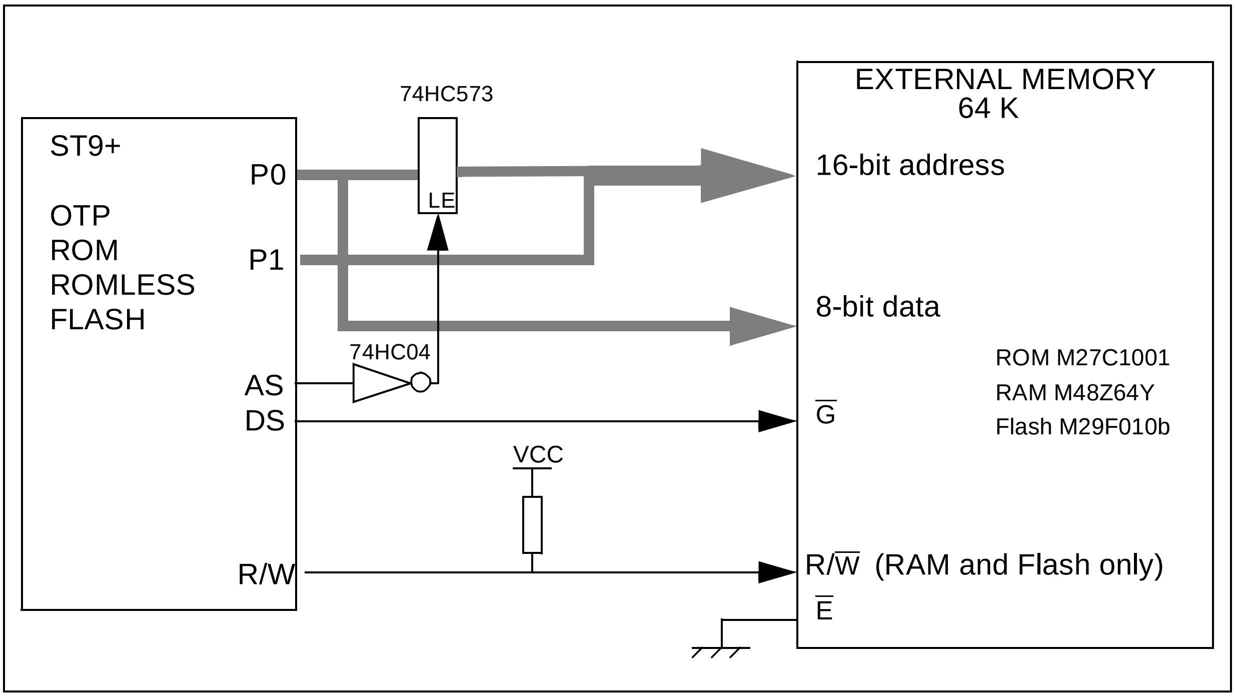


In the first part of this application note we will see how to use the existing interface to address 64 Kbytes or 128 Kbytes (ST92F120 only) of external memory without any additional software overhead. In the second part we will see how to address almost 2 Mbytes with a ROMLESS or almost 4 Mbytes with an OTP/EPROM/FLASH device. This last solution uses the P2 I/O port to output the 22-bit address.

2 ACCESSING UP TO 64 KBYTES OF EXTERNAL MEMORY WITHOUT SOFTWARE OVERHEAD

The ST9+ outputs a 16-bit address multiplexed with the 8-bit data. So, to access 64 Kbytes of memory, we only need to make the correct hardware connections between the memory devices and the microcontroller. These connections are described in Figure 2..

Figure 2. Accessing 64 Kbytes of external memory



The R/W signal is only needed for RAM and Flash or mixed memory components. The pull-up resistor is needed only when using ROMLESS devices.

Examples of memory mapping are given in Figure 3. and Figure 4..

Figure 3. Memory mapping for 64K of external memory with ST90158 (OTP)

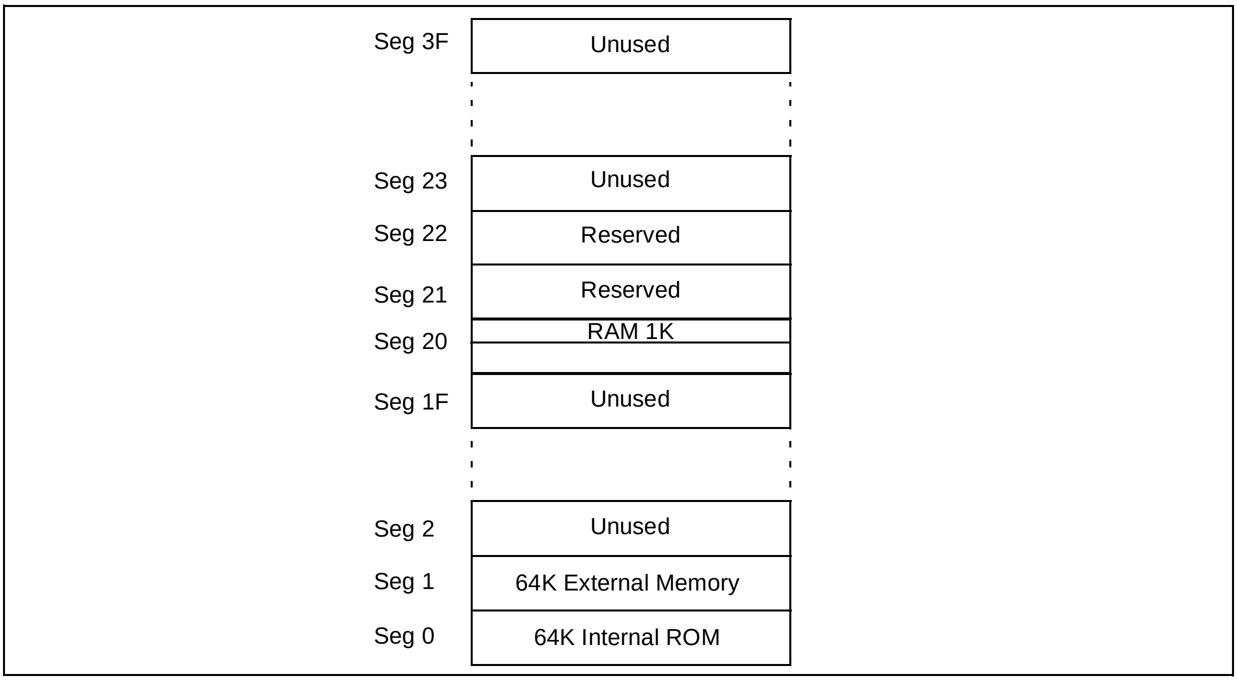
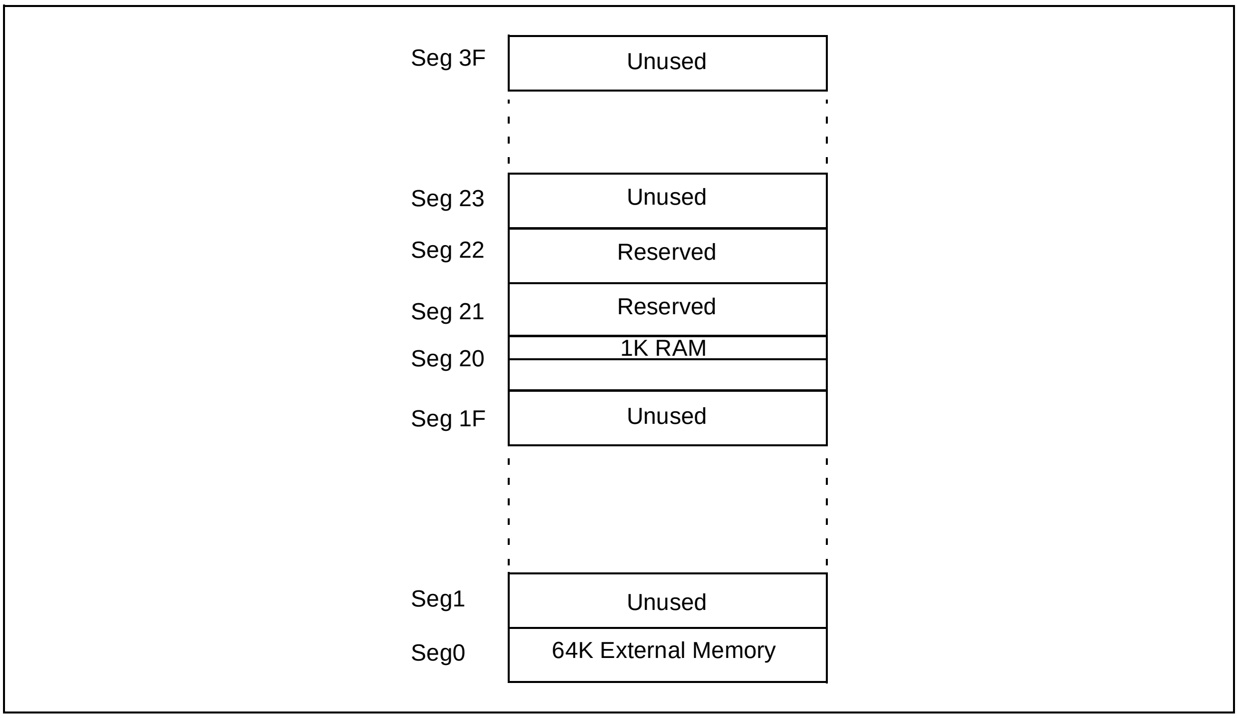


Figure 4. Memory mapping for 64 K of external memory with ST90R158 (ROMLESS)



3 ACCESSING UP TO 2 OR 4 MBYTES WITH ANY ST9+

3.1 PRINCIPLE

As previously mentioned in Section 1, the ST9 handles 22-bit addresses internally but outputs only the 16 LSBs of the address through the external memory interface. In this section we will see how, by handling it in software, it is possible to access almost 2M with a ROMLESS device or almost to 4M bytes with an OTP, ROM, or Flash device.

To access more than 64K of external memory, you need to output the 6 Most Significant Bits (MSBs) of the address. To do this, we have chosen to use the 6 LSBs of Port 2 (refer to Figure 5.).

Port 2 will be used by software to select the Dynamic Segment you want to access.

External memory segments and Internal memory segments are two different addressable areas. For simplicity, both types of segment are numbered in the same way.

Figure 5. ST9+ Schematic

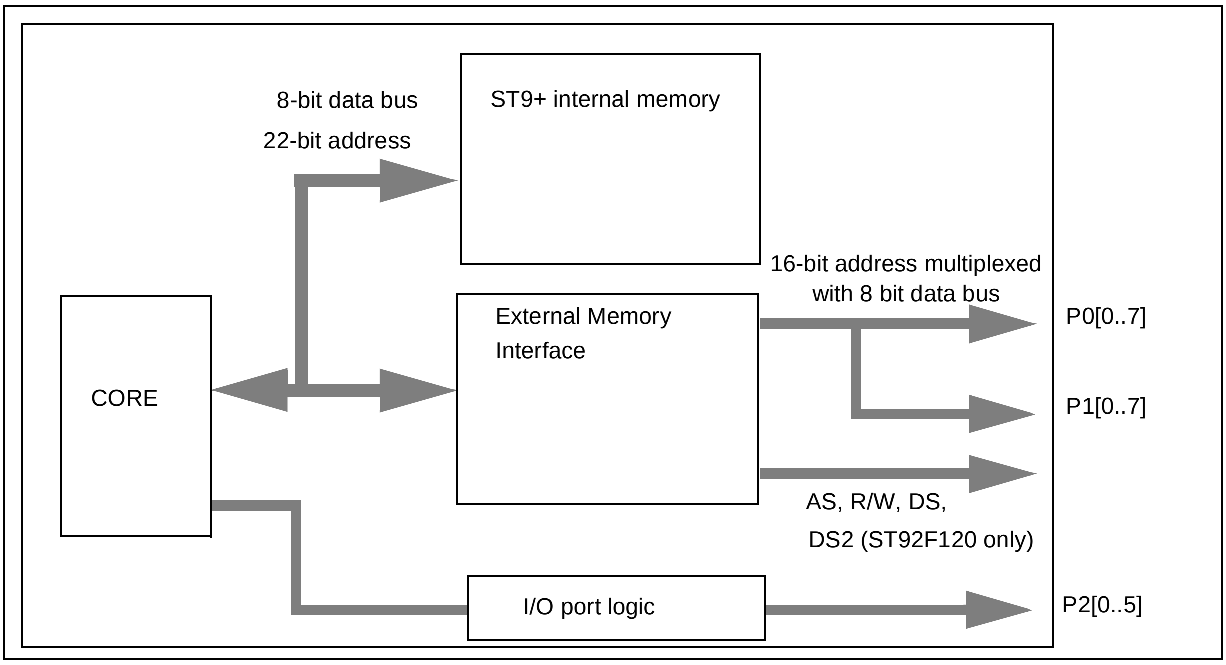
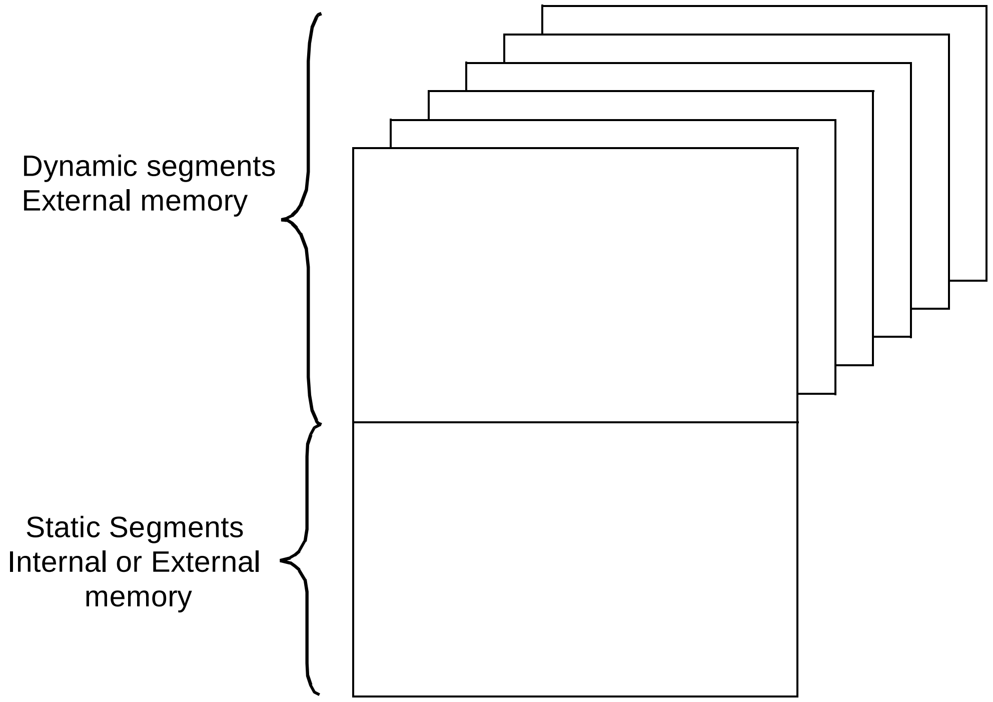


Figure 6. Static and Dynamic Segments



3.2 DEFINITION

STATIC SEGMENT (SS): A segment of memory which can always be accessed whatever the value of the Dynamic Segment selected (value of Port 2 data register: P2DR). In an OTP/ ROM/FLASH microcontroller, the internal memory can always be accessed and therefore is contained in static segments. For example in the ST90158, Segment 0 (ROM) and Seg 20 (RAM) are static segments

The size of the memory in a segment can be from zero to 64K. The number of static segments and the amount of memory in each segment depends on the microcontroller.

In the case of ROMLESS devices, the static segment must be a special area of external memory which is not connected to Port 2 and is therefore not dynamic.

At least one static segment is needed in any application.

DYNAMIC SEGMENT (DS): A segment of the external memory which is accessible only if it has been selected by the user. Its access depends on the P2DR (Port 2 data register) value. The size of a dynamic segment can be from 0 to 64K.

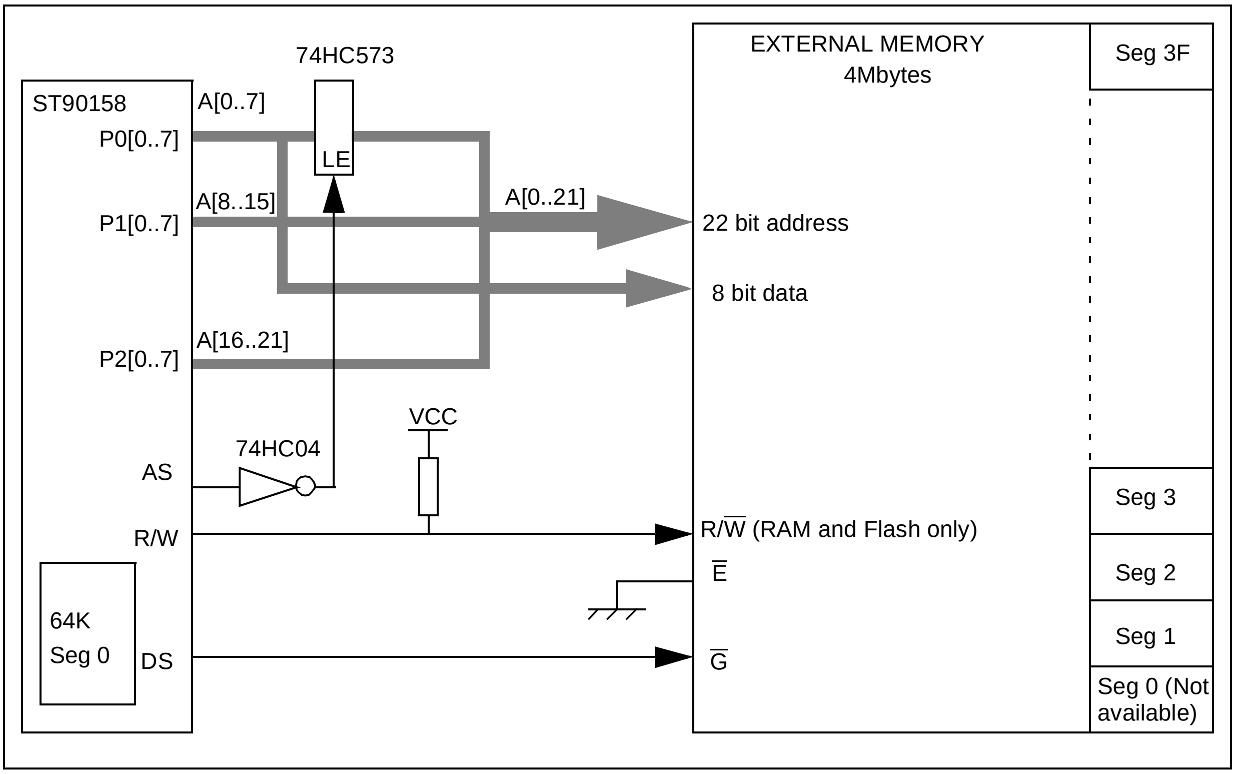
3.3 HARDWARE IMPLEMENTATION

3.3.1 Example using a microcontroller with internal memory

In this example, using the ST90158 with 64K of internal ROM, the microcontroller's internal memory can be used as a Static Segment.

The hardware connections are shown in Figure 7..

Figure 7. Accessing almost 4M with the ST90158



Due to the fact we are using OTP or ROM devices, when the user accesses an address in the internal segment, no external signals (AS, DS...) will be output by the ST9+ if the ETO bit in the EMR1 register is correctly configured (please refer to the datasheet). This is the case for segments: 0, 21, 22 and 23h in the ST90158. Therefore any external memory that uses the same segment number as the internal memory will not be accessible. To make it accessible, we would need a dedicated logical unit.

Using the ST90158, the maximum accessible memory will be:

4M (total accessible memory)

- 4 x 64 k (internal segments)

+ 1K (internal RAM)

+ 64K (internal ROM)

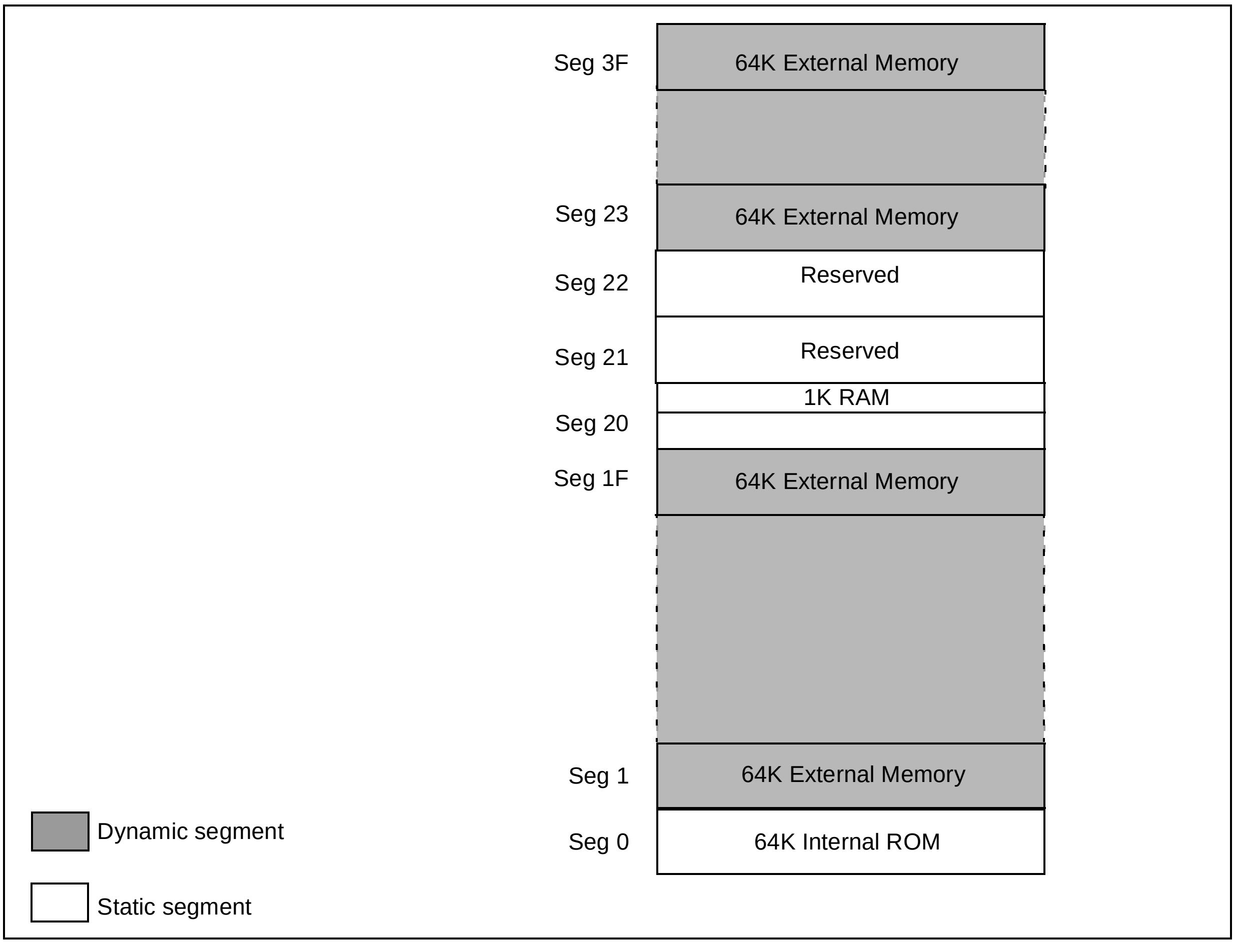
____

= 3905K bytes

The size of each dynamic segment is 64 Kbytes in this case. We can represent the memory seen by the microcontroller as shown in Figure 8..

Note: When using ST92F120, it is not possible to access any external segments other than segments 2 and 3. So the maximum amount of external memory that can be accessed by the ST92F120 is 128 Kbytes.

Figure 8. Memory map for accessing 4M of external memory with the ST90158



3.3.2 Example Using a ROMless microcontroller

If we use a ROMLESS ST90158 device (which has no internal ROM), we cannot use internal memory as a Static Segment, therefore we have to create an external Static Segment. An example of the hardware implementation is given in Figure 9.. The external memory capability is divided into 2 parts, the Static segments and the Dynamic segments. In this example, A15 is used to select either Static or Dynamic segments. As a consequence of this, the Static and Dynamic Segments are 32K bytes in size so we can access only 32k of external memory in each segment. If you compare the address of the external memory described in Figure 9. and the address of the ST9 described in Figure 10., you can see the difference starts from the 16th bit of the address.

Like in ST90158 OTP devices, Segments 20, 21, 22 of external memory cannot be accessed. The total accessible memory is:

2M (64 Kbytes x 64 segments)

-3 x 32K (internal segment)

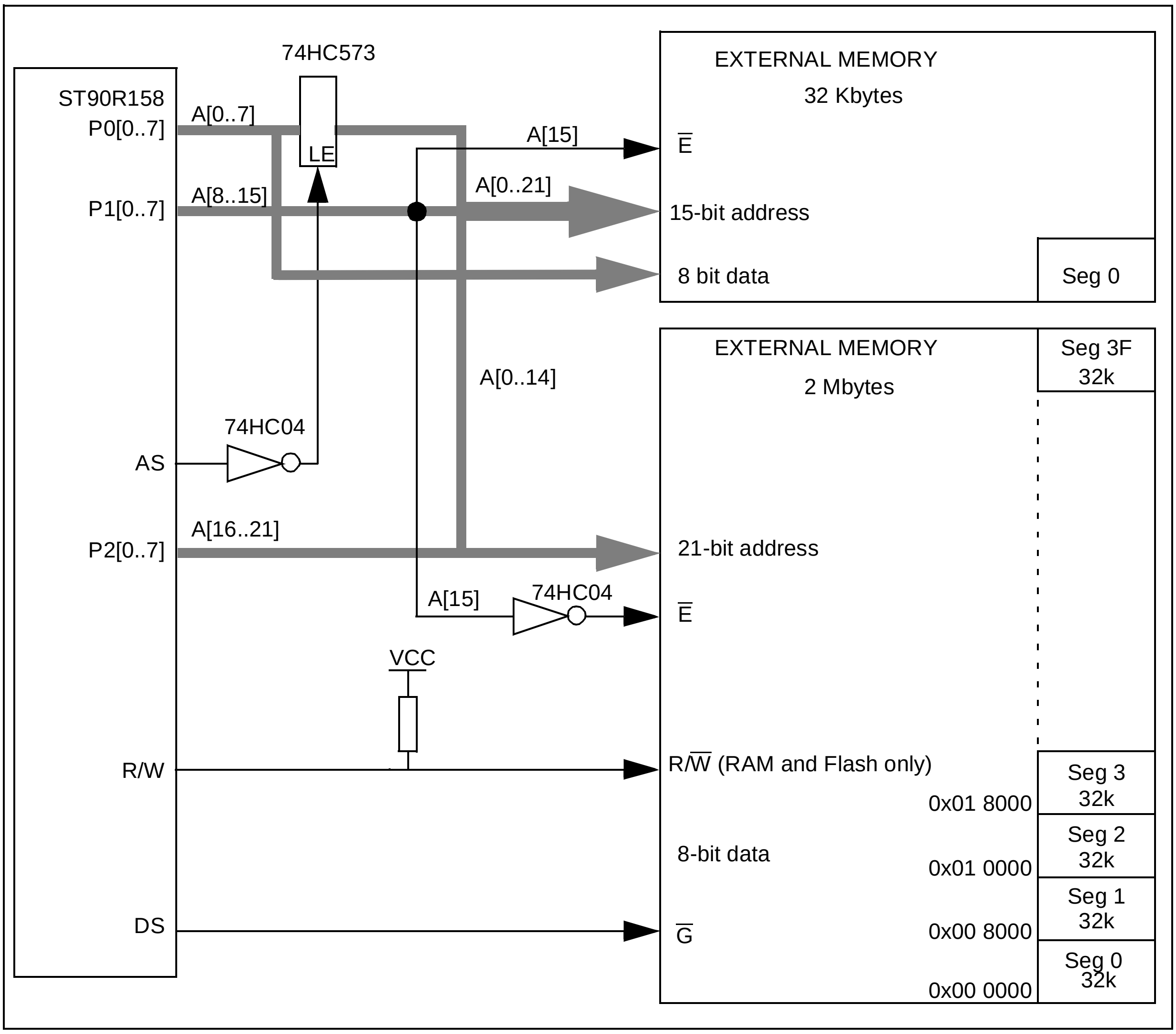
+32K (static page)

<u>+1K (internal RAM)</u>

=1920K bytes

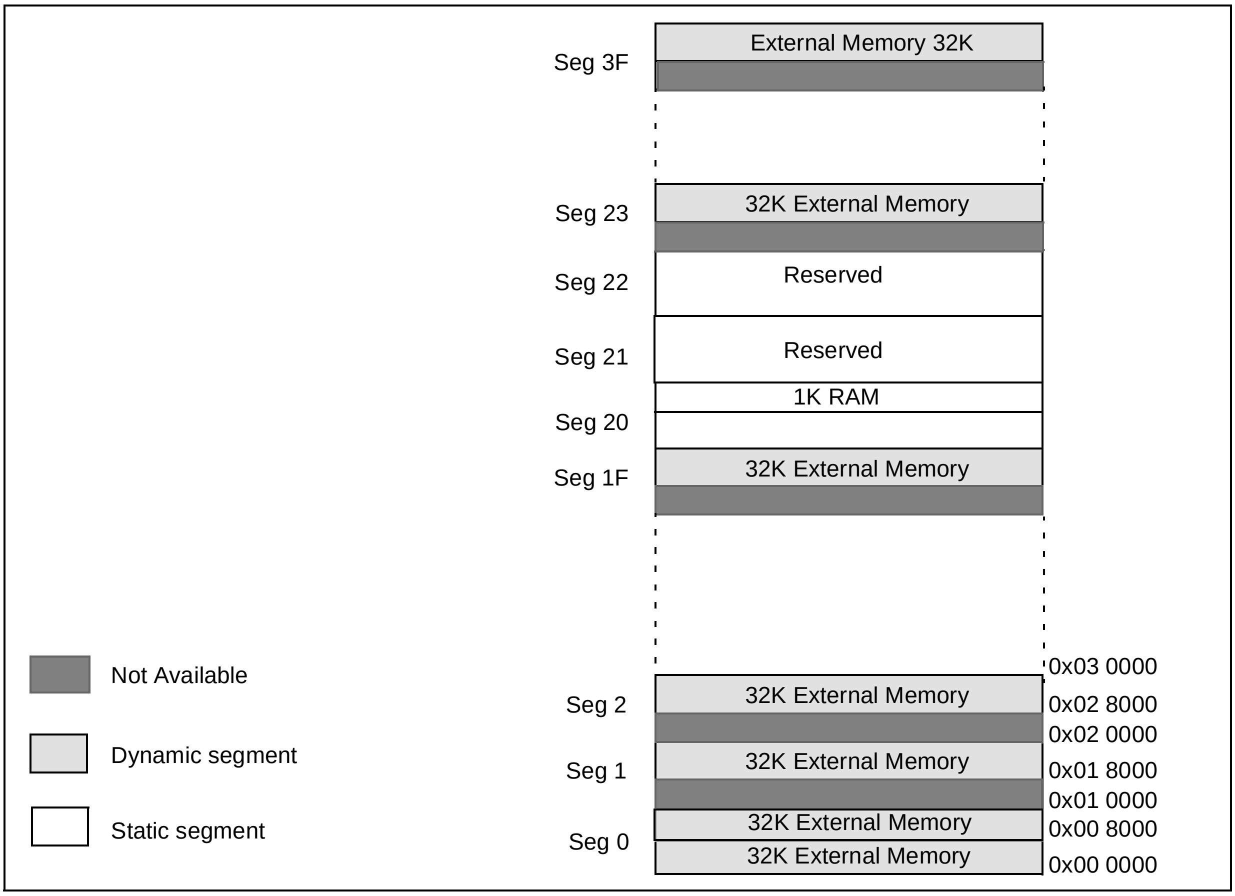
Figure 10. shows the memory map with segments containing 32K of memory.

Figure 9. Accessing almost 2M with the ST90R158



It is possible to increase the amount of accessible memory by reducing the size of the static would increase the complexity of the hardware and software.

Figure 10. Memory mapping for accessing 2M of external memory with ST90R158



3.4 SOFTWARE IMPLEMENTATION

3.4.1 Calling functions or manipulating data in a dynamic segment

Before calling a function or manipulating data in a Dynamic Segment we need to write the correct value in the Port 2 data register (P2DR) to select the segment. This can be done automatically using a macro called “set_seg()” which is in the “extmem.h” file. This macro uses the function name or the data address as a parameter:

```
set_seg(my_function_name)
set_seg(&data_name)
```

This macro must be used each time we want to call a function or manipulate data which is in a dynamic Segment other than the current one. It is not necessary to use this macro to call a function in the same dynamic segment as the caller function or to manipulate data in the same dynamic. Nevertheless, for data manipulation is advised to set the segment using the macro for code portability. Once this macro is implemented in your code, if you change the location of your code to another Dynamic Segment, the segment number is computed automatically. Nevertheless make sure you change the associated data segment too, since code cannot access data located in another Dynamic Segment.

The number of instructions and cycles generated by this macro depends on the location of the P2DR register, it can go from 3 bytes, 6 cycles to 5 bytes 10 cycles. Depending on the DPRREM bit in the EMR2 Register, the P2DR register can be located in group E of the Register File (RF) or in group F page 21 of the RF. Read the datasheet and C-compiler manual carefully since the programming model has an impact on the DPRREM register.

3.4.2 Direct Memory Access (DMA)

The following paragraph is about DMA transfer between a peripheral and memory. There are no restrictions on DMA transfer between a peripheral and the Register File.

In most applications, the DMA can occur at any moment during program execution. Data to be transferred needs to be located in the Static Segment. Nevertheless, if it is really needed, we can put the data in the Dynamic Segment. But during DMA, we can only run code in the Static Segments or in the same Static Segment as the one where the data is located.

3.4.3 INTERRUPTS

Interrupts can occur at any time during code execution. Therefore, interrupt vectors and routines should be located in the Static Segment in order to be accessible at any time.

Nevertheless, a routine from a Dynamic Segment can be called by the interrupt routine. In this case, refer to the datasheet to be sure you have configured your microcontroller to save the CSR (refer to the description of the ENCSR bit in the EMR2 register).

3.4.4 Emulation

For emulation, during the down load of the application into the emulator, the access to the dynamic segments cannot be configured properly since the emulator is in reset state. To get around this, we can use the internal memory of the emulator as a buffer and then transfer the information from the emulator memory (declared as SYSTEM memory in the Mapfile of ST Visual Debugger (STVD9) to the external memory (declared as USER memory in the Map file of STVD9). This operation is done in the Start up file of the software example after the initialization of the external memory interface (if needed). It is done by the secinfo table. Refer to GCC9 user manual for more information on the secinfo section.

By using this process, we need twice as much memory since any external memory needs to have a buffer. Therefore the maximum amount of memory available during emulation is 2MB.

3.4.5 Capabilities and limitations

Due to the fact that dynamic segments can only be accessed one by one, some limitations apply to the way you write your program and manipulate data. Table 1 summarizes the capabilities and limitations.

Table 1. Software capabilities and limitations

Type of data	Location	Capability	Emulation
Code	Execution in SS or DS	Yes	OK
	Jump or call from SS to DS	Yes	OK
	Jump or call from DS to SS	Yes	OK
	Jump or call from DS to another DS	NO	N/A
	Jump or call from DS to the same DS	Yes	OK
Constant	Located in the SS and used by a program in the SS or DS	Yes	Always seen
	Located in the DS and used by a program in the SS or the same DS as the constant	Yes	Not seen if the DS is not selected
	Located in the DS and used by a program in another DS	No	N/A
Initialized variables	Located in the SS and used by a program in the SS or DS	Yes	Always seen
	Located in the DS and used by a program in the SS or the same DS as the constant	Yes	Not seen if the DS is not selected
	Located in the DS and used by a program in another DS	No	N/A
Un-initialized variables	Located in the SS and used by a program in the SS or DS	Yes	Always seen
	Located in the DS and used by a program in the SS or the same DS as the constant	Yes	Not seen if the DS is not selected
	Located in the DS and used by a program in another DS	No	N/A

Legend: SS = Static Segment, DS = Dynamic Segment.

3.5 SOFTWARE EXAMPLE

A software example using the ST9 demonstration board and the ST90158EMU2B is available.

You will find in it examples all the possible code manipulations (call...) and use of data (constants, initialized variables...). You will be able to observe the transfer process for the emulation capability. The example downloads the program into the external RAM of the demonstration board.

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