

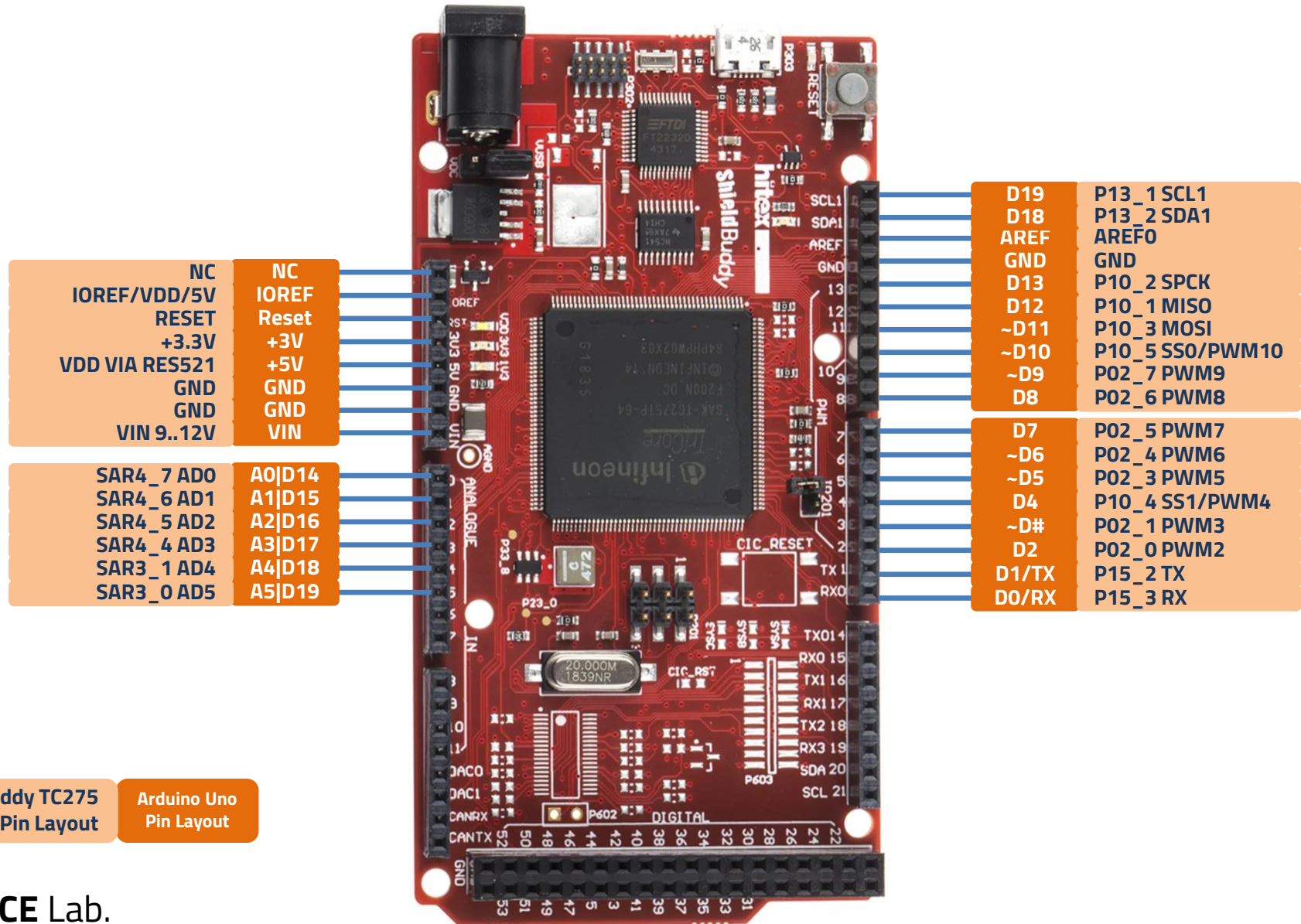
Infineon TC275 Interrupt

Architecture and Compiler for Embedded System LAB.
School of Electronics Engineering, KNU, KOREA

2021-05-11



Hitex ShieldBuddy TC275



ShieldBuddy TC275
Pin Layout

Arduino Uno
Pin Layout

Interrupt Flow in TC275

1. External Request Input을 External Request Unit (ERU)이 처리함

- ✓ 각 Input Channel에 있는 ERS에서 4개의 가능한 입력 중 하나의 입력 벡터를 선택함

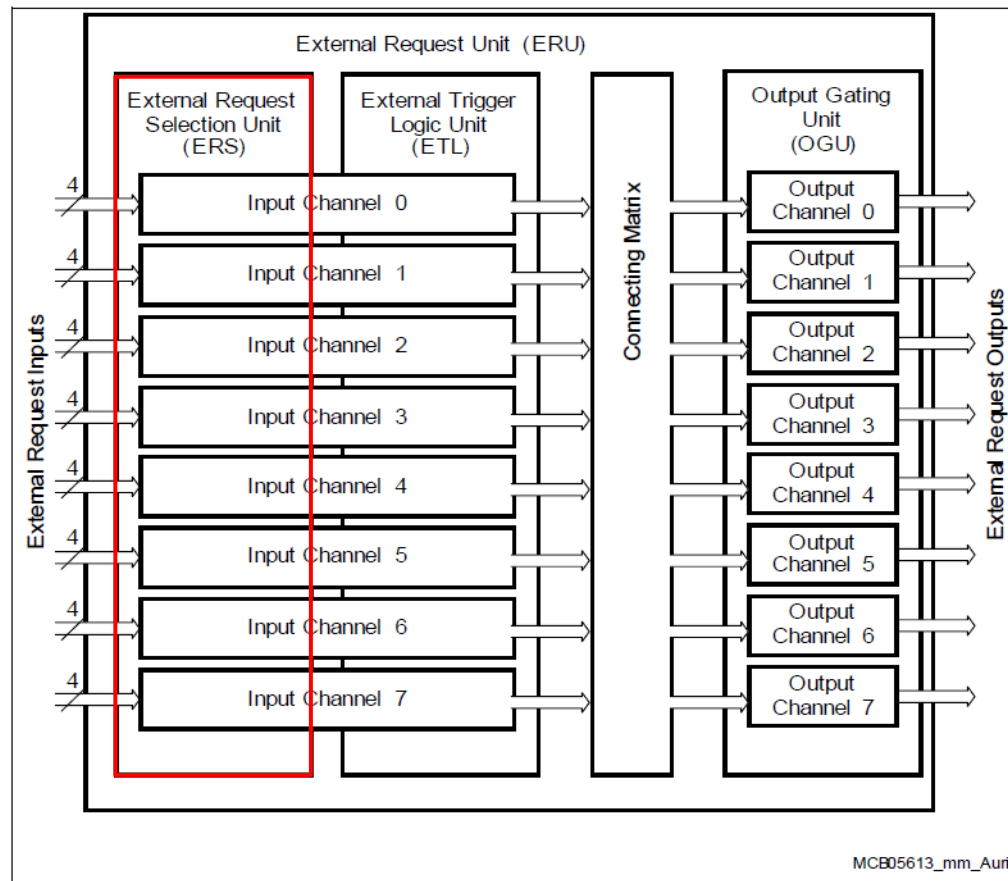


Figure 7-40 External Request Unit Overview

Interrupt Flow in TC275

1. External Request Input을 External Request Unit (ERU)이 처리함
 - ✓ 각 Input Channel에 있는 ETL이 지정된 엣지에서 입력을 트리거 이벤트로 전환함

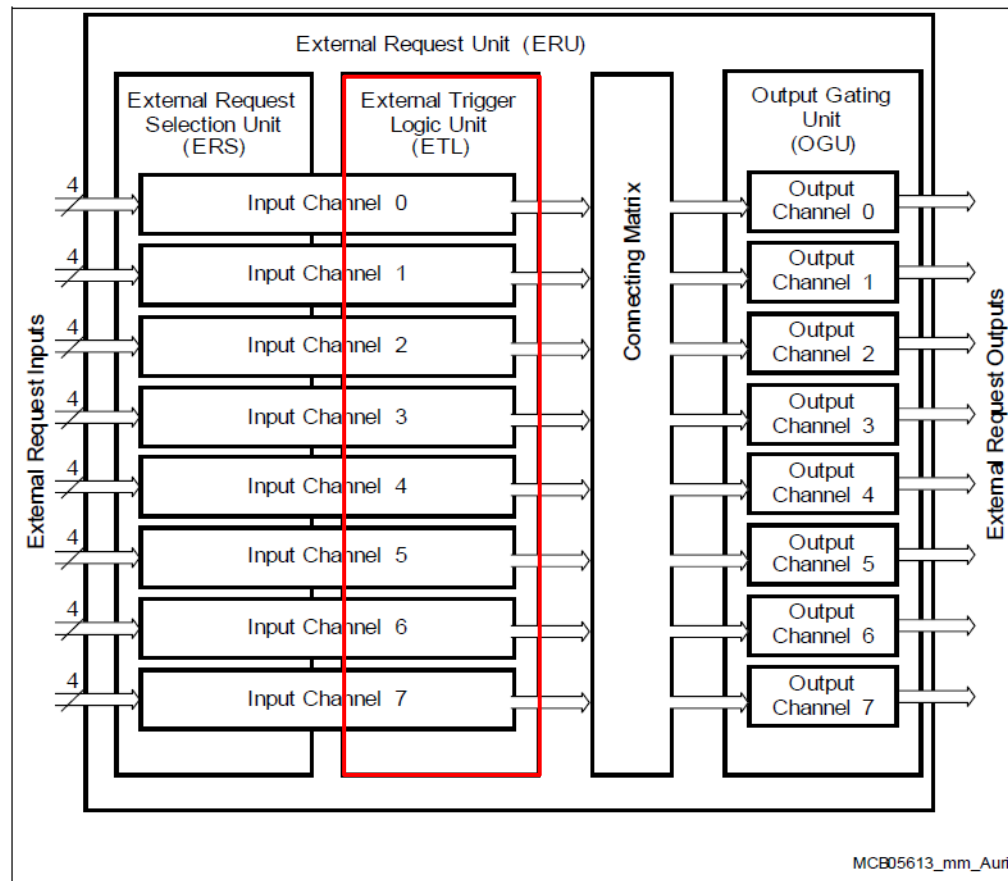


Figure 7-40 External Request Unit Overview

Interrupt Flow in TC275

1. External Request Input을 External Request Unit (ERU)이 처리함

- ✓ Connecting Matrix는 입력 채널에서 생성된 이벤트를 출력 채널로 배포함

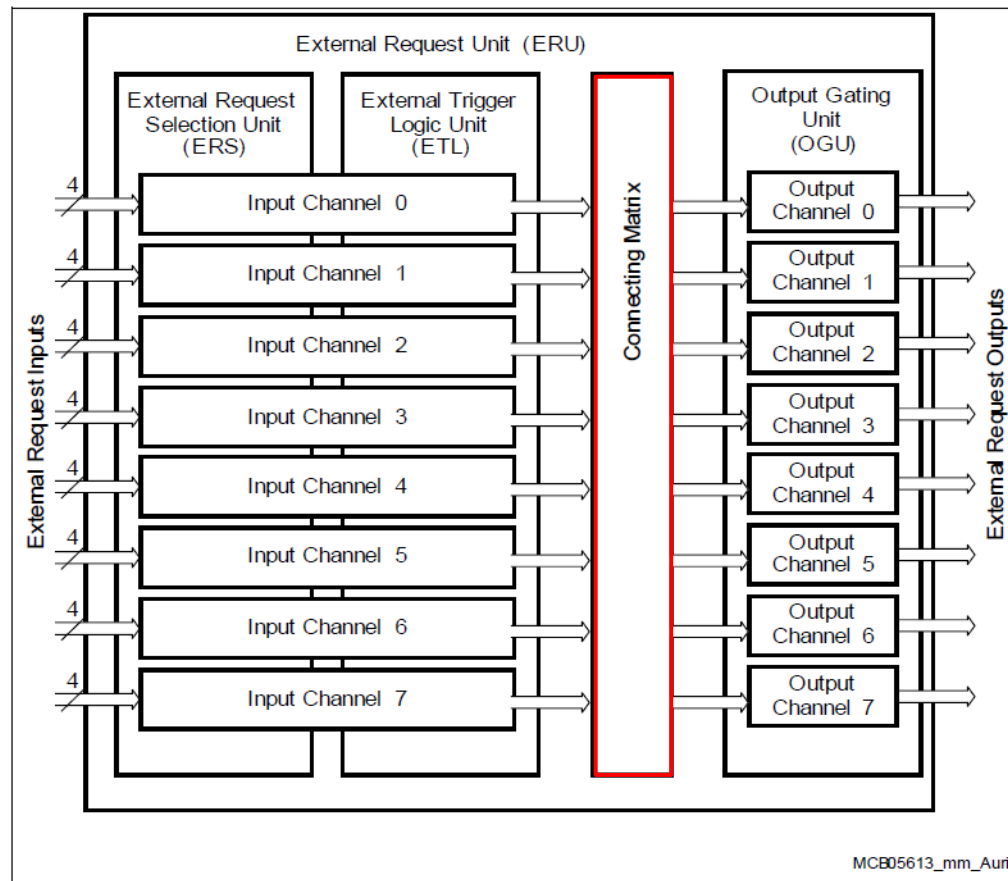


Figure 7-40 External Request Unit Overview

Interrupt Flow in TC275

1. External Request Input을 External Request Unit (ERU)이 처리함

- ✓ Output Gating Unit은 Input Channel로 부터의 트리거 이벤트와 상태 정보를 조합하여 출력을 내보냄
- ✓ 하나의 이벤트가 여러 채널에 갈 수 있고 여러 이벤트가 하나의 채널에서 패턴을 만들 수 있음

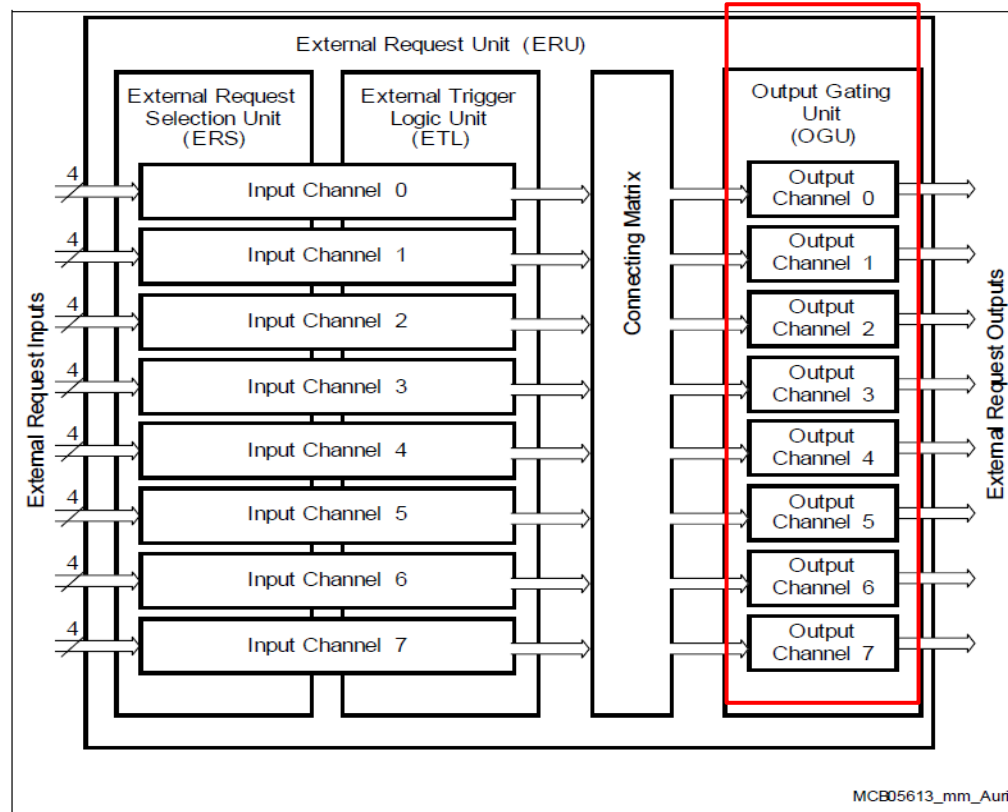


Figure 7-40 External Request Unit Overview

Interrupt Flow in TC275

2. ERU의 출력이 Interrupt Router (IR)의 입력이 됨

- ✓ OGU에서 나온 출력이 연결된 Service Request Nodes (SRN)의 입력이 됨
- ✓ SRN은 모든 Interrupt Control Units (ICU)에 연결되어 있고 Service Request Control Register (SRC) 설정을 통해 가능한 Service Provider (CPU0-2, DMA)에 매핑함
- ✓ 각 ICU는 ICU에 매핑된 SRN의 Service Request 간의 인터럽트 중재를 처리함

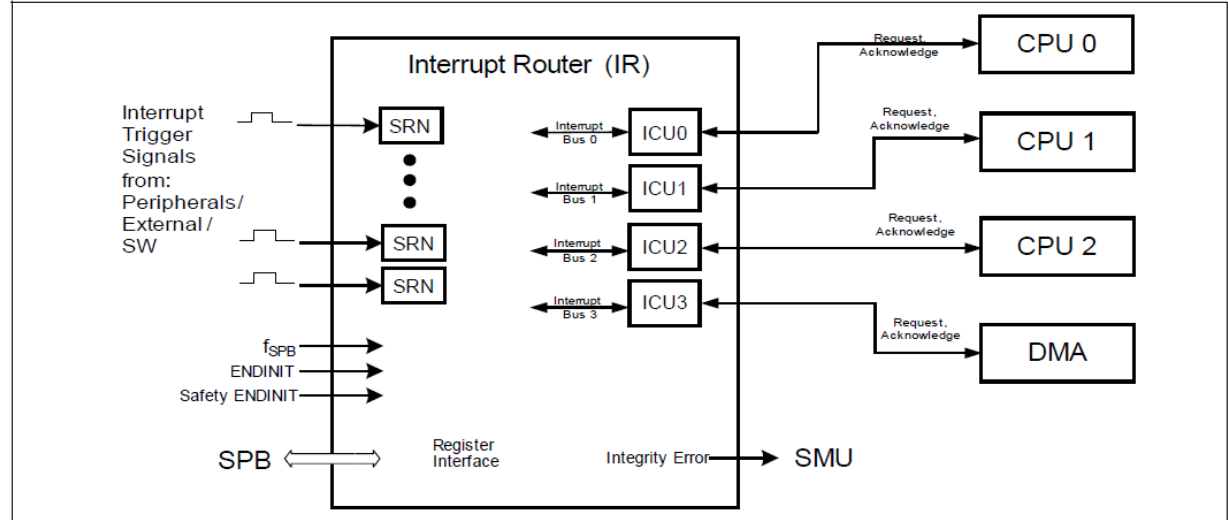
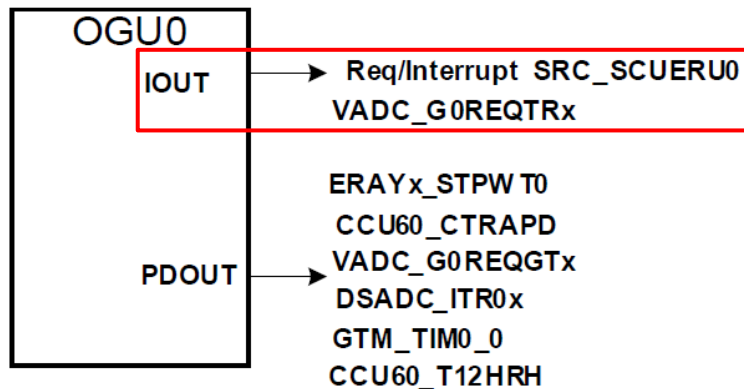


Figure 16-1 Block Diagram of the TC27x Interrupt System

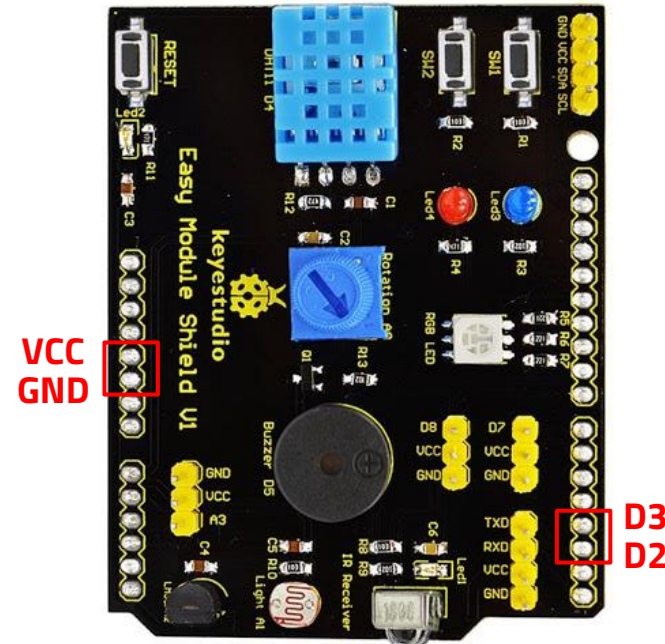
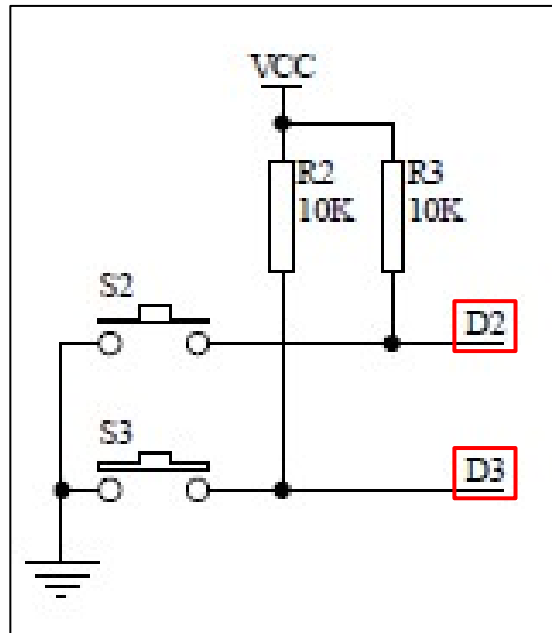
External Interrupt Example

- External Interrupt를 사용하여 Switch를 눌렀을 때 LED Toggle
 1. 새로운 예제를 위한 프로젝트를 생성한다.
 2. 원하는 동작을 위해 레지스터와 메모리에 직접 접근해서 값을 써야한다.
 3. Switch 사용을 위해 Board Schematic과 Datasheet에서 Switch 연결 정보를 파악한다.
 4. External Interrupt를 사용하기 위해 Datasheet를 분석한다.
 5. 분석 결과를 활용해 임베디드 프로그래밍을 한다.

External Interrupt Example

1. Switch 연결 정보 파악

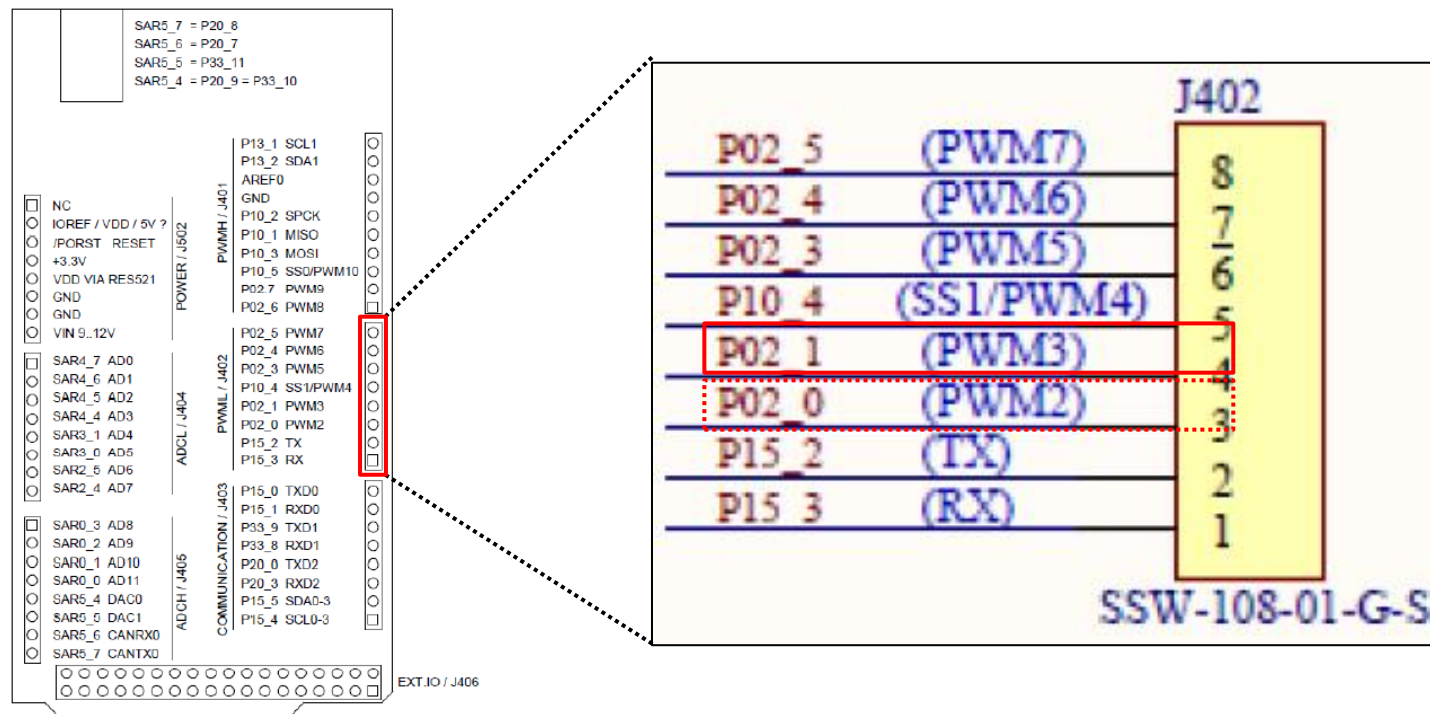
- ✓ Switch는 Easy Module Shield V1 확장 보드의 **Pin D2/D3**과 연결되어 있다.
- ✓ Switch가 눌리면 연결된 Pin은 Low-level이 되고, Switch가 눌리지 않으면 연결된 Pin은 High-level이 된다.
- ✓ 타겟 보드는 Easy Module Shield V1 확장 보드의 Pin D2/D3을 통해 Switch 입력을 받을 수 있다.
(정상적인 Switch 동작을 위해 VCC 및 GND도 연결해야 한다.)



External Interrupt Example

1. Switch 연결 정보 파악

- ✓ TC275 보드의 Schematic과 Datasheet를 확인했을 때, Easy Module Shield V1 확장 보드의 **Pin D3**와 연결되는 IO는 **PORT02의 Pin 1**다.



External Interrupt Example

2. Data sheet 분석 : IO 설정

- ✓ Switch에 의한 External Interrupt를 사용하기 위해 연결된 Pin의 IO 설정이 필요하다.
- ✓ Switch가 연결된 PORT02 Pin 1은 External Interrupt를 관리하는 **SCU (System Control Unit) 내 ERU (External Request Unit)의 REQ14**와 연결되어 있다.
- ✓ 따라서, PORT02 Pin 1을 **Input**으로 설정하여 Switch 신호를 **ERU의 입력**으로 설정해야 한다.

2	P02.1	I	LP / PU1 / VEXT	General-purpose input
	TIN1			GTM input
	REQ14			SCU input
	ARX2B			ASCLIN2 input
	RXDCAN0A			CAN node 0 input
	RXDA2			ERAY input
	CIFD1			CIF input
	P02.1	O0		General-purpose output
	TOUT1	O1		GTM output
	—	O2		Reserved
	SLSO32	O3		QSPI3 output
	DSCGPWMP	O4		DSADC output
	—	O5		Reserved
	—	O6		Reserved
	COUT60	O7		CCU60 output

External Interrupt Example

2. Data sheet 분석 : PORT 설정 (1)

- ✓ P02_IOCR Register는 PORT02의 Input/Output을 설정한다.
- ✓ Switch가 PORT02의 Pin 1에 연결되어 있기 때문에 **P02_IOCR0 Register의 PC1 bits**를 설정한다.

Table 13-3 Registers Address Space

Module	Base Address	End Address	Note
P00	F003 A000 _H	F003 A0FF _H	13 pins
P01	F003 A100 _H	F003 A1FF _H	5 pins
P02	F003 A200 _H	F003 A2FF _H	12 pins
P10	F003 B000 _H	F003 B0FF _H	9 pins
P11	F003 B100 _H	F003 B1FF _H	16 pins
P12	F003 B200 _H	F003 B2FF _H	2 pins
P13	F003 B300 _H	F003 B3FF _H	4 pins
P14	F003 B400 _H	F003 B4FF _H	11 pins
P15	F003 B500 _H	F003 B5FF _H	9 pins

P02_IOCR0 Register 주소: F003_A210h (F003A200h + 10h)

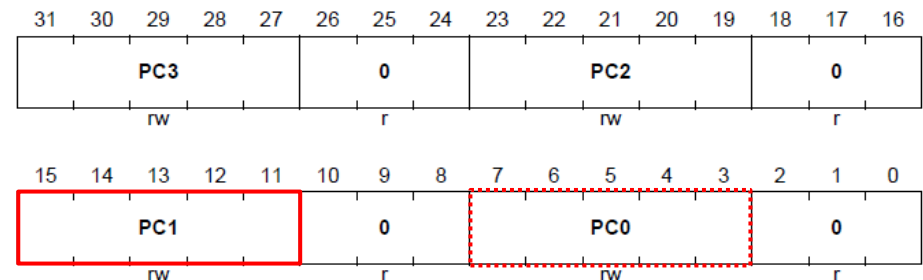
P02_IOCR0 Register 구조:

P02_IOCR0

Port 02 Input/Output Control Register 0

(10_H)

Reset Value: 1010 1010_H



Field	Bits	Type	Description
PC0, PC1, PC2, PC3	[7:3], [15:11], [23:19], [31:27]	rw	Port Control for Port n Pin 0 to 3 This bit field determines the Port n line x functionality (x = 0-3) according to the coding table (see Table 13-5).
0	[2:0], [10:8], [18:16], [26:24]	r	Reserved Read as 0; should be written with 0.

External Interrupt Example

2. Data sheet 분석 : PORT 설정 (2)

- ✓ Easy Module Shield V1의 Switch는 pull-up device이다.
- ✓ 따라서, PORT02의 Pin 1을 Input으로 설정할 때 **PC1 bits**를 **0XX10b**로 설정한다.

Table 13-5 PCx Coding

PCx[4:0]	I/O	Characteristics	Selected Pull-up / Pull-down / Selected Output Function
0XX00 _B	Input	—	No input pull device connected, tri-state mode
0XX01 _B			Input pull-down device connected
0XX10 _B			Input pull-up device connected ¹⁾
0XX11 _B			No input pull device connected, tri-state mode

The diagram illustrates the input connections for seven Event Reduction Subsystems (ERS0 to ERS7). Each ERS block lists its inputs and their corresponding In pins. ERS0 and ERS1 are outside a red box, while ERS2, ERS3, ERS4, ERS5, ERS6, and ERS7 are inside it. REQ14 (P02.1) and REQ6 (P02.0) are highlighted with red boxes.

ERS0

- REQ0 (P15.4) → In0
- CCU60_COUT60 → In01
- REQ4 (P10.7) → In02
- MSC0_FCLP → In03

ERS1

- REQ10 (P14.3) → In10
- CCU61_COUT60 → In11
- REQ5 (P10.8) → In12
- STM0_STMIR0 → In13

ERS2

- REQ2 (P10.2) → In20
- REQ14 (P02.1) → In21
- REQ7 (P00.4) → In22
- ERAY0_MT → In23

ERS3

- REQ3 (P10.3) → In30
- REQ15 (P14.1) → In31
- REQ6 (P02.0) → In32
- STM1_STMIR0 → In33

ERS4

- REQ8 (P33.7) → In40
- GTM TOM 0_12 → In41
- GPT120_T30UT → In42
- REQ13 (P15.5) → In43

ERS5

- REQ1 (P15.8) → In50
- GTM TOM 1_12 → In51
- GPT120_T60UT → In52
- STM2_STMIR0 → In53

ERS6

- REQ9 (P20.0) → In60
- ESR0 → In61
- Reserved → In62
- REQ12 (P11.10) → In63

ERS7

- REQ11 (P20.9) → In70
- ESR1 → In71
- REQ16 (P15.1) → In72
- Reserved → In73

ERU_Inputs_Overview_TC27x

Figure 7-41 External Request Unit Input Connections for TC27x

External Interrupt Example

2. Data sheet 분석 : ERU External Input Channel 설정 (1)

- ✓ SCU_EICR Register는 ERU의 External input Channel 0-7에 대한 설정을 한다.
- ✓ 하나의 SCU_EICR Register는 2개의 Channel에 대한 설정을 한다.
(SCU_EICR0: Channel 0-1, SCU_EICR1: Channel 2-3, SCU_EICR2: Channel 4-5, ...)
- ✓ PORT02 Pin 1과 연결된 REQ14가 **ERU의 Channel 2 Input 1**과 연결되어 있기 때문에 **SCU_EICR1 Register의 INP0 bits / EIEN0 bit / FENO bit / EXIS0 bits**를 설정한다.

SCU_EICR1 Register 주소: F003_6214h (F0036000h + 214h)

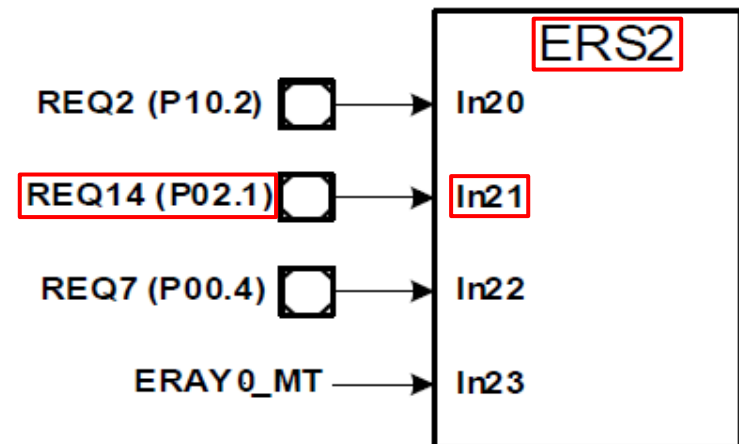
SCU_EICR1 Register 구조:

Table 7-27 Registers Address Spaces - SCU Kernel Registers

Module	Base Address	End Address	Note
SCU	F003 6000 _H	F003 63FF _H	-

EICR1
External Input Channel Register 1 (214_H) Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0	INP1			EI EN1	LD EN1	R EN1	F EN1	0	EXIS1					0	
r	rw			rw	rw	rw	rw	r	rw					r	
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	INP0			EI EN0	LD EN0	R EN0	F EN0	0	EXIS0					0	
r	rw			rw	rw	rw	rw	r	rw					r	



External Interrupt Example

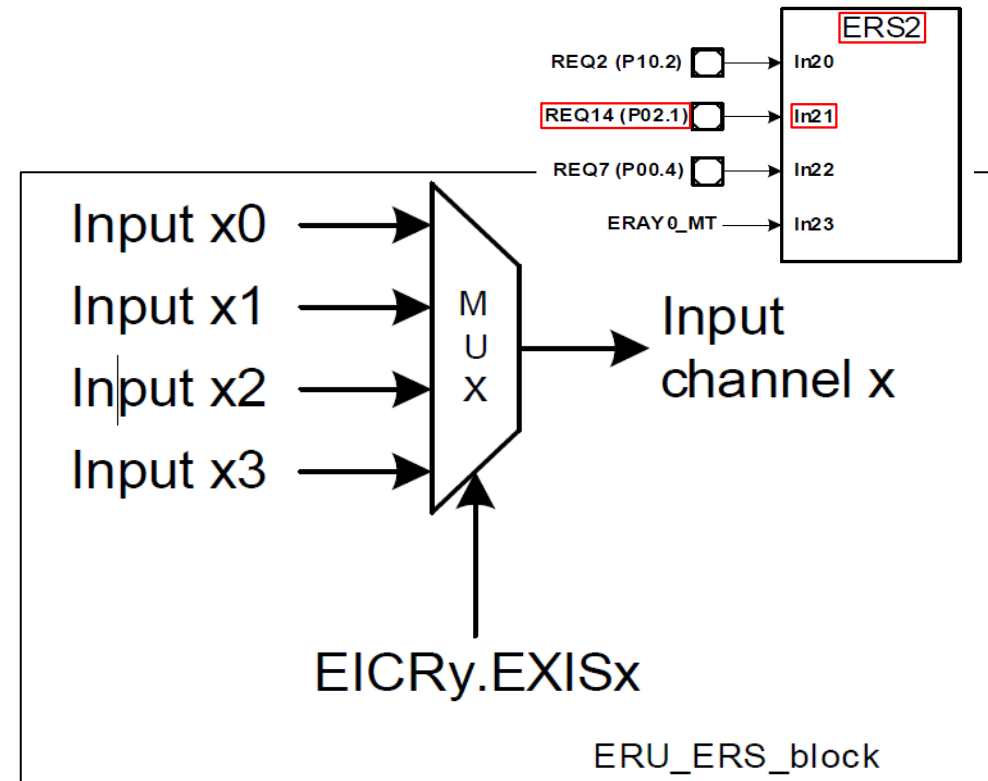
2. Data sheet 분석 : ERU External Input Channel 설정 – Channel Selection

- ✓ ERU의 각 External Input Channel은 여러 개의 External Request Input을 입력 받기 때문에 이들 중 하나의 입력을 결정해야 한다.
- ✓ PORT02 Pin 10이 ERU의 Channel 2 Input 1과 연결되어 있기 때문에 **EXIS0 bits**를 **001b**로 설정한다.

EICR1
External Input Channel Register 1 (214_H) Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0	INP1		EI EN1	LD EN1	R EN1	F EN1	0	EXIS1				0 ESR3			
r	rw		rw	rw	rw	rw	r	rw				r			
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	INP0		EI EN0	LD EN0	R EN0	F EN0	0	EXIS0				0 ESR2			
r	rw		rw	rw	rw	rw	r	rw				r			

Field	Bits	Type	Description
EXIS0	[6:4]	rw	External Input Selection 0 This bit field determines which input line is selected for Input Channel (2i). 000 _B Input (2i) 0 is selected 001 _B Input (2i) 1 is selected 010 _B Input (2i) 2 is selected 011 _B Input (2i) 3 is selected 100 _B Reserved 101 _B Reserved 110 _B Reserved 111 _B Reserved



External Interrupt Example

2. Data sheet 분석 : ERU External Input Channel 설정 – Trigger Enable & Edge Selection

- ✓ Switch가 pull-up device이기 때문에 Switch가 눌렸을 때, 신호는 High-level에서 Low-level로 바뀌며 Falling edge가 발생한다.
- ✓ 따라서, Falling edge가 검출되었을 때 트리거 신호 (for External Interrupt)를 생성하기 위해 **FENO bit**를 1로 설정한다.
- ✓ 생성된 트리거 신호를 Enable 하기 위해 **EIENO bit**를 1로 설정한다.

EICR1
External Input Channel Register 1 (214_H) Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0	INP1		EI EN1		LD EN1	R EN1	F EN1	0	EXIS1				0		
r	rw		rw		rw	rw	rw	r	rw				r		

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	INP0		EI EN0		LD EN0	R EN0	F EN0	0	EXIS0				0		
r	rw		rw		rw	rw	rw	r	rw				r		

Field	Bits	Type	Description
FENO	8	rw	Falling Edge Enable 0 This bit determines if the falling edge of Input Channel (2i) is used to set bit INTF(2i). 0 _B The falling edge is not used 1 _B The detection of a falling edge of Input Channel 0 generates a trigger event. INTF(2i) becomes set.
REN0	9	rw	Rising Edge Enable 0 This bit determines if the rising edge of Input Channel (2*i) is used to set bit INTF(2i). 0 _B The rising edge is not used 1 _B The detection of a rising edge of Input Channel (2*i) generates a trigger event. INTF(2*i) becomes set
LDEN0	10	rw	Level Detection Enable 0 This bit determines if bit INTF(2i) is cleared automatically if an edge of the input Input Channel (2i) is detected, which has not been selected (rising edge with REN0 = 0 or falling edge with FENO = 0). 0 _B Bit INTF(2i) will not be cleared 1 _B Bit INTF(2i) will be cleared
EIENO	11	rw	External Input Enable 0 This bit enables the generation of a trigger event for request channel (2i) (e.g. for interrupt generation) when a selected edge is detected. 0 _B The trigger event is disabled 1 _B The trigger event is enabled

External Interrupt Example

2. Data sheet 분석 : Connecting Matrix 설정

- ✓ ERU의 각 External Input Channel에서 생성된 트리거 신호는 Connecting Matrix를 통해 Output Channel에 전달된다.
- ✓ Output Channel은 입력 받은 트리거 신호를 Interrupt 신호로 전달할 수 있다.
- ✓ 생성된 트리거 신호를 Output Channel 0에 전달하기 위해 **INP0 bits**를 **000b**로 설정한다.

EICR1

External Input Channel Register 1 (214_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0	INP1			EI EN1	LD EN1	R EN1	F EN1	0	EXIS1			0			
r	rw			rw	rw	rw	rw	r	rw			r			

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	INP0			EI EN0	LD EN0	R EN0	F EN0	0	EXIS0			0			
r	rw			rw	rw	rw	rw	r	rw			r			

Field	Bits	Type	Description
INP0	[14:12]	rw	Input Node Pointer This bit field determines the destination (output channel) for trigger event (2i) (if enabled by EIEN(2i)). 000 _B An event from input ETL 2i triggers output OGU0 (signal TR(2i) 0) 001 _B An event from input ETL 2i triggers output OGU1 (signal TR(2i) 1) 010 _B An event from input ETL 2i triggers output OGU2 (signal TR(2i) 2)

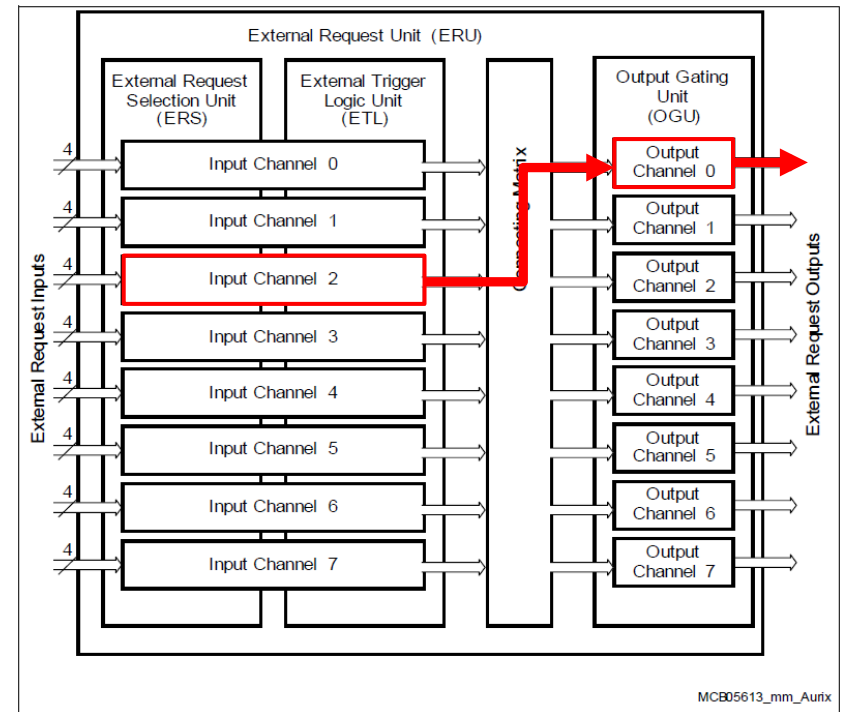


Figure 7-40 External Request Unit Overview

External Interrupt Example

2. Data sheet 분석 : ERU Flag Gating 설정 (1)

- ✓ SCU_IGCR Register는 ERU의 Output Channel 0-7에 대한 설정을 한다.
- ✓ 하나의 SCU_IGCR Register는 2개의 Channel에 대한 설정.
(SCU_IGCR0: Channel 0-1, SCU_IGCR1: Channel 2-3, ...)
- ✓ External Input Channel 2에서 생성된 트리거 신호가 Output Channel 0에 전달되기 때문에
SCU_IGCR0 Register의 IGPO bits를 01b로 설정한다.

SCU_IGCR0 Register 주소: F003_622Ch (F0036000h + 22Ch)

SCU_IGCR0 Register 구조:

Table 7-27 Registers Address Spaces - SCU Kernel Registers

Module	Base Address	End Address	Note
SCU	F003 6000 _H	F003 63FF _H	-

IGCR0 Flag Gating Register 0 (22C _H) Reset Value: 0000 0000_H															
31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
IGP1		GE EN1	0				IPEN	IPEN	IPEN	IPEN	IPEN	IPEN	IPEN	IPEN	IPEN
rw		rw	r				rw	rw	rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
IGP0		GE EN0	0				IPEN	IPEN	IPEN	IPEN	IPEN	IPEN	IPEN	IPEN	IPEN
rw		rw	r				rw	rw	rw	rw	rw	rw	rw	rw	rw

oooooo

Field	Bits	Type	Description
IGP0	[15:14]	rw	Interrupt Gating Pattern 0 In each register IGCRj, bit field IGP0 determines how the pattern detection influences the output lines GOUT(2j) and IOUT(2j). 00 _B IOUT(2j) is inactive. The pattern is not considered.
			01 _B IOUT(2j) is activated in response to a trigger event. The pattern is not considered.
			10 _B The detected pattern is considered. IOUT(2j) is activated if a trigger event occurs while the pattern is present.
			11 _B The detected pattern is considered. IOUT(2j) is activated if a trigger event occurs while the pattern is not present.

External Interrupt Example

2. Data sheet 분석 : Interrupt Router 설정 (1)

- ✓ Interrupt Router는 Interrupt Trigger를 Service Providers (CPU 0-2, DMA)에 연결한다.
- ✓ Switch 신호에 따라 ERU에서 생성된 트리거 신호는 **Output Channel 0의 IOOUT**으로 출력된다.
- ✓ 해당 출력은 Interrupt Router의 **SCUERU0 SRN (Service Request Node)**와 연결된다.
- ✓ 해당 노드에 대한 설정을 하기 위해 **SRC_SCUERU0 Register**를 설정해야 한다.

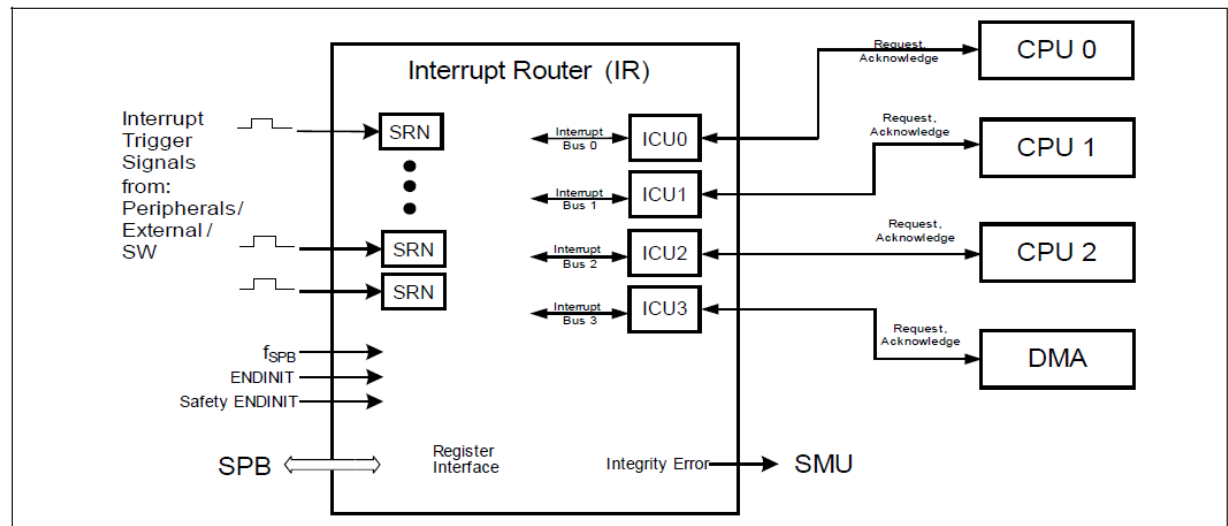
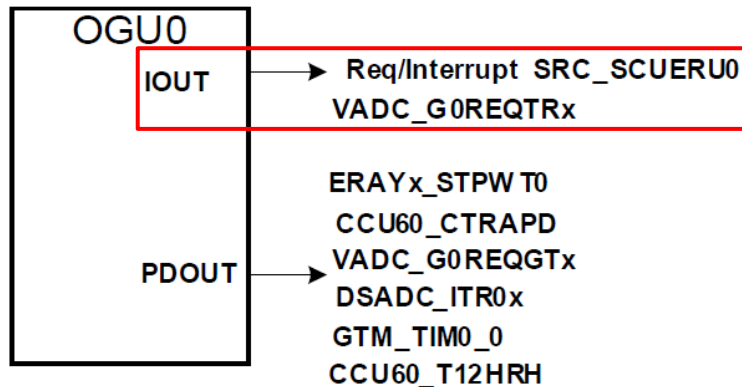


Figure 16-1 Block Diagram of the TC27x Interrupt System

External Interrupt Example

EICR0	External Input Channel Register 0	210 _H	U, SV	U, SV, P	Application Reset	Page 7-239
EICR1	External Input Channel Register 1	214 _H	U, SV	U, SV, P	Application Reset	Page 7-239
EICR2	External Input Channel Register 3	218 _H	U, SV	U, SV, P	Application Reset	Page 7-239
EICR3	External Input Channel Register 4	21C _H	U, SV	U, SV, P	Application Reset	Page 7-239
EIFR	External Input Flag Register	220 _H	U, SV	BE	Application Reset	Page 7-243
FMR	Flag Modification Register	224 _H	U, SV	U, SV, P	Application Reset	Page 7-244
PDRR	Pattern Detection Result Register	228 _H	U, SV	BE	Application Reset	Page 7-245

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V2.2, 2014-12



TC27x D-Step

Table 7-28 Register Overview of SCU (Offset from Main Register Base)

Short Name	Long Name	Offset Addr. 1)	Access Mode		Reset	Description See
			Read	Write		
IGCR0	Interrupt Gating Register 0	22C _H	U, SV	U, SV, P	Application Reset	Page 7-246
IGCR1	Interrupt Gating Register 1	230 _H	U, SV	U, SV, P	Application Reset	Page 7-246
IGCR2	Interrupt Gating Register 2	234 _H	U, SV	U, SV, P	Application Reset	Page 7-246
IGCR3	Interrupt Gating Register 3	238 _H	U, SV	U, SV, P	Application Reset	Page 7-246

Table 2 Access Terms

Symbol	Description
U	Access Mode: Access permitted in User Mode 0 or 1. Reset Value: Value or bit is not changed by a reset operation.
SV	Access permitted only in Supervisor Mode.
R	Read-only register.
32	Only 32-bit word accesses are permitted to this register/address range.
32/16	Only 32-bit or 16-bit accesses are permitted to this register/address range.
CEx	CPUx Endinit protected register/address.
SE	Safety Endinit protected register/address.
E	Any CPU Endinit-protected register/address.
P (or P0 / P1)	Access Enable Register protected register/address. (ACCEN0/1)
PW	Password-protected register/address.
NC	No change, indicated register is not changed.
BE	Indicates that an access to this address range generates a Bus Error.
nBE	Indicates that no Bus Error is generated when accessing this address range, even though it is either an access to an undefined address or the access does not follow the given rules.
nE	Indicates that no Error is generated when accessing this address or address range, even though the access is to an undefined address or address range. True for CPU accesses (MTCR/MFCR) to undefined addresses in the CSFR range.

1.1.5 Abbreviations and Acronyms

The following acronyms and terms are used in this document:

ADC	Analog-to-Digital Converter
ALU	Arithmetic and Logic Unit
ASCLIN	Asynchronous/Synchronous Serial Controller with LIN
BCU	Bus Control Unit
BROM	Boot ROM & Test ROM
CAN	Controller Area Network
CAPCOM	Capture Compare Unit

External Interrupt Example



TC27x D-Step

Password Access to WDTxCON0

A correct password must be written to register WDTxCON0 (x=S, CPU0, CPU1 or CPU2) in order to unlock it for modifications. Software must either know the correct password in advance or compute it at runtime. The passwords for each of the Watchdogs (x=S, CPU0, CPU1 or CPU2) can be different in order to provide independent watchdog functionality program flows to have independent watchdog functions.

The Safety Watchdog password register WDTSCON0 is protected by the generic SCU protection scheme which allows only configured master(s) to have write access (See ACCEN0).

CPU-specific Watchdog password registers WDTCPUyCON0 are individually protected such that they may only be written by the corresponding CPUy

A watchdog may be used within a safety application to provide a recovery time period during which software might attempt to recover from a safety alarm warning. To ensure that a CPU fault could not allow a fault to be ignored an option is provided to prevent watchdog unlocking if the Safety Management Unit (SMU) is not in the RUN state. This option may be enabled by bit WDTxCON0.UR.

If the password is valid and the SMU state meets the requirements of the WDTxCON0.US bit then WDTxCON0 will be unlocked as soon as the Password Access is completed. The unlocked condition will be indicated by WDTxCON0.LCK = 0. To ensure the correct servicing sequence, a password access is only permitted when the WDTxCON0.LCK bit was set prior to the access.

If an improper password value is written to WDTxCON0 during the Password Access, a Watchdog Access Error condition exists. Bit WDTxSR.AE is set and an alarm request is sent to the Safety Management Unit (SMU).

The 14-bit user-definable password, WDTxCON0.PW, provides additional options for adjusting the password requirements to the application's needs. It can be used, for instance, to detect unexpected software loops, or to monitor the execution sequence of routines.

Table 7-24 summarizes the requirements for the password. Various options exist, which are described in more detail below



TC27x D-Step

7.4.8.3 SCU Access Restriction Registers

The Access Enable Register 0 restricts write access to all SCU registers so that they may only be written by specified bus masters (eg CPUs). See the Bus chapter for the mapping of TAG ID to specific system masters and CPUs).

ACCEN0

Access Enable Register 0 (3FC_H) Reset Value: FFFF FFFF_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
EN 31	EN 30	EN 29	EN 28	EN 27	EN 26	EN 25	EN 24	EN 23	EN 22	EN 21	EN 20	EN 19	EN 18	EN 17	EN 16
RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
EN 15	EN 14	EN 13	EN 12	EN 11	EN 10	EN 9	EN 8	EN 7	EN 6	EN 5	EN 4	EN 3	EN 2	EN 1	EN 0
RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW

Field	Bits	Type	Description
ENn (n = 0-31)	n	RW	Access Enable for Master TAG ID n This bit enables write access to the SCU kernel addresses for transactions with the Master TAG ID n 0 _B Write access will not be executed 1 _B Write access will be executed

ACCEN1

Access Enable Register 1 (3F8_H) Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0															
r															

External Interrupt Example

2. Data sheet 분석 : Safety Critical Register 설정 (1)

- ✓ 설정해야 하는 SCU_EICR1 / SCU_IGCR0 Register는 Safety Critical Register이기 때문에 Write Protected (Safety ENDINIT, End-of-Initialization) 되어 있다.
- ✓ 해당 Register를 수정하기 위해서는 Safety ENDINIT을 해제해야 한다.
- ✓ SCU_WDTSCON0 Register는 **Safety Critical Register**에 대한 **Safety ENDINIT**을 설정/해제한다.

SCU_WDTSCON0 Register 주소: F003_60F0h
(F0036000h + 0F0h)

SCU_WDTSCON0 Register 구조:

Table 7-27 Registers Address Spaces - SCU Kernel Registers

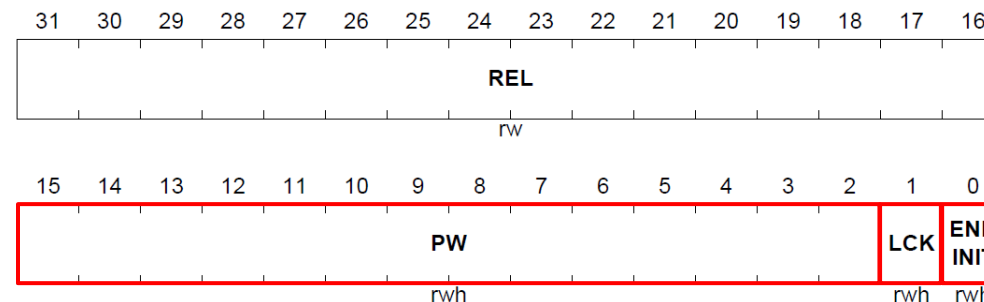
Module	Base Address	End Address	Note
SCU	F003 6000 _H	F003 63FF _H	-

WDTSCON0

Safety WDT Control Register 0

(0F0_H)

Reset Value: FFFC 000E_H



External Interrupt Example

2. Data sheet 분석 : Safety Critical Register 설정 (2)

- ✓ **ENDINIT bit**는 Safety ENDINIT의 설정 상태를 나타내며 Modify Access를 통해서만 수정이 가능하다.
- ✓ **LCK bit**는 SCU_WDTSCON0 Register의 Lock 상태를 나타내며 해당 Register의 Lock 상태는 Password Access를 통해 Unlock 되고, Modify Access를 통해 Lock 된다.
- ✓ **PW bits**는 SCU_WDTSCON0 Register에 접근하기 위한 Password를 저장하며 해당 값을 읽으면 bits[7:2]가 반전되어 읽힌다.

Field	Bits	Type	Description
ENDINIT	0	rwh	End-of-Initialization Control Bit 0 _B Access to Endinit-protected registers is permitted. 1 _B Access to Endinit-protected registers is not permitted. This bit must be written with a '1' during a Password Access or Check Access (although this write is only used for the password-protection mechanism and is not stored). This bit must be written with the required ENDINIT update value during a Modify Access.
LCK	1	rwh	Lock Bit to Control Access to WDTxCON0 0 _B Register WDTxCON0 is unlocked 1 _B Register WDTxCON0 is locked (default after ApplicationReset) The current value of LCK is controlled by hardware. It is cleared after a valid Password Access to WDTxCON0 when WDTxSR.US is 0 (or when WDTxSR.US is 1 and the SMU is in RUN mode), and it is automatically set again after a valid Modify Access to WDTxCON0. During a write to WDTxCON0, the value written to this bit is only used for the password-protection mechanism and is not stored. This bit must be cleared during a Password Access to WDTxCON0, and set during a Modify Access to WDTxCON0. A Check Access does not clear LCK.

PW	[15:2]	rwh	User-Definable Password Field for Access to WDTxCON0 This bit field is written with an initial password value during a Modify Access. A read from this bitfield returns this initial password, but bits [7:2] are inverted (toggled) to ensure that a simple read/write is not sufficient to service the WDT. If corresponding WDTxSR.PAS = 0 then this bit field must be written with its current contents during a Password Access or Check Access. If corresponding WDTxSR.PAS = 1 then this bit field must be written with the next password in the LFSR sequence during a Password Access or Check Access The default password after Application Reset is 00000000111100 _B A-step silicon: Bits [7:2] must be written with 111100 _B during Password Access and Modify Access. Read returns 000011 _B for these bits.
----	--------	-----	--




External Interrupt Example

2. Data sheet 분석 : Safety Critical Register 설정 (3)

- ✓ SCU_WDTSCON0 Register에 적절한 값을 Write하여 **Password Access**를 수행한다.
- ✓ **Password Access**는 **SCU_WDTSCON0 Register의 Lock 상태를 해제**하며 과정은 다음과 같다.
 1. SCU_WDTSCON0 Register의 값을 읽어 REL bits, PW bits를 파악한다.
 2. Bits[7:2] (PW bits의 일부)가 반전되어 읽히기 때문에 이를 반전시켜 정확한 PW bits를 얻는다.
 3. Write 할 값의 bits[31:16]은 읽혀진 REL bits 값으로 설정하고 bit[15:2]는 앞서 구한 정확한 PW bits 값으로 설정한다.
 4. Write 할 값의 bit[1]은 **unlock(write 0)** 후, bit[0]은 **0**으로 설정한다.
(Safety ENDINIT 설정: bit[0] = 1, Safety ENDINIT 해제 : bit[0] = **0**)
 5. 설정된 값을 SCU_WDTSCON0 Register에 한번에 쓴다.
 6. SCU_WDTSCON0 Register의 LCK bit를 확인하여 Lock 상태가 해제되었는지 파악한다.
(Password Access가 정상적으로 수행되면 Lock 상태가 해제되며 LCK bit가 **0**으로 설정된다.)
- ✓ Password Access를 통해 SCU_WDTSCON0 Register의 Lock 상태가 해제되면 Modify Access를 통해 Safety ENDINIT을 설정/해제할 수 있다.

External Interrupt Example

2. Data sheet 분석 : Safety Critical Register 설정 (4)

- ✓ SCU_WDTSCON0 Register에 적절한 값을 Write하여 **Modify Access**를 수행한다.
 - ✓ **Modify Access**는 **Safety ENDINIT**을 **설정/해제**하며 과정은 다음과 같다.
 1. SCU_WDTSCON0 Register의 값을 읽어 REL bits, PW bits를 파악한다.
 2. Bits[7:2] (PW bits의 일부)가 반전되어 읽히기 때문에 이를 반전시켜 정확한 PW bits를 얻는다.
 3. Write 할 값의 bits[31:16]은 읽혀진 REL bits 값으로 설정하고 bit[15:2]는 앞서 구한 정확한 PW bits 값으로 설정한다.
 4. Write 할 값의 bit[1]은 **unlock(write 0)** 후, bit[0]은 **1**로 설정한다.
(Safety ENDINIT 설정: bit[0] = **1**, Safety ENDINIT 해제 : bit[0] = 0)
 5. 설정된 값을 SCU_WDTSCON0 Register에 한번에 쓴다.
 6. SCU_WDTSCON0 Register의 LCK bit를 확인하여 Lock 상태가 다시 설정되었는지 파악한다.
(Modify Access가 정상적으로 수행되면 Lock 상태가 설정되며 LCK bit가 **1**로 설정된다.)
 - ✓ Modify Access를 통해 Safety ENDINIT을 해제하면 Safety Critical Register를 수정할 수 있으며
-  ACE 설정을 완료하면 Safety ENDINIT을 꼭 다시 설정해야 한다.

External Interrupt Example

3. 프로그래밍

1) Switch 및 LED가 연결된 PORT에 대한 설정을 수행하는 함수를 구현한다.

✓ 자세한 내용은 이전 강의자료 (GPIO)를 참고한다.

```
31 #define PORT10_BASE      (0xF003B000)
32 #define PORT10_IOCR0     (*(volatile unsigned int*)(PORT10_BASE + 0x10))
33 #define PORT10_OMR       (*(volatile unsigned int*)(PORT10_BASE + 0x04))
34
35 #define PC1               11
36 #define PC2               19
37
38 #define PCL1              17
39 #define PCL2              18
40 #define PS1               1
41 #define PS2               2
```

PORT13 IO (LED RED) 설정관련 레지스터 주소 및 비트 필드 정의

```
45 /* Initialize LED (RED & BLUE) */
46 void init_LED(void)
47 {
48     /* Reset PC1 & PC2 in IOCR0 */
49     PORT10_IOCR0 &= ~((0x1F) << PC1);
50     PORT10_IOCR0 &= ~((0x1F) << PC2);
51
52     /* Set PC1 & PC2 with push-pull(2b10000) */
53     PORT10_IOCR0 |= ((0x10) << PC1);
54     PORT10_IOCR0 |= ((0x10) << PC2);
55 }
```

PORT13 IO (LED RED) 설정 초기화 코드

External Interrupt Example

3. 프로그래밍

1) Switch 및 LED가 연결된 PORT에 대한 설정을 수행하는 함수를 구현한다.

✓ 자세한 내용은 이전 강의자료 (GPIO)를 참고한다.

```
40 /* Define PORT02 Registers for Switch2 */
41 #define PORT02_BASE      (0xF003A200)
42 #define PORT02_IOCR0     (*(volatile unsigned int*)(PORT02_BASE + 0x10))
43 #define PORT02_IN        (*(volatile unsigned int*)(PORT02_BASE + 0x24))
44
45 #define PC1              11
46 #define P1               1
```

PORT02 IO (Switch2) 설정관련 레지스터 주소 및 비트 필드 정의

```
60 /* Initialize Switch2 */
61 void init_Switch(void)
62 {
63     /* Reset PC1 in IOCR0*/
64     PORT02_IOCR0 &= ~((0x1F) << PC1);
65
66     /* Set PC1 with push-pull(2b0xx10) */
67     PORT02_IOCR0 |= ((0x2) << PC1);
68 }
```

PORT02 IO (Switch2) 설정 코드

External Interrupt Example

3. 프로그래밍

2) ERU를 설정하기 위한 함수를 구현한다.

- ① SCU_WDTSCON0 Register를 통해 Password/Modify Access를 수행하여 Safety ENDINIT을 해제한다.
- ② SCU_EICR1 Register를 통해 ERU의 Channel 2의 입력으로 Input 1을 설정한다.
- ③ SCU_EICR1 Register를 통해 Falling edge가 트리거 신호를 생성하도록 설정하고 이를 Enable 한다.
- ④ SCU_EICR1 Register를 통해 생성된 트리거 신호가 Output Channel 0에 전달되도록 한다.
- ⑤ SCU_IGCR0 Register를 통해 전달된 트리거 신호가 IOUT으로 출력되도록 설정한다.
- ⑥ SCU_WDTSCON0 Register를 통해 Password/Modify Access를 수행하여 Safety ENDINIT을 설정한다.
- ⑦ SRC_SCUERU0 Register를 통해 SCUERU0 SRN의 우선순위를 설정한다.
- ⑧ SRC_SCUERU0 Register를 통해 SCUERU0 SRN의 처리가 CPU0에서 수행되도록 설정한다.
- ⑨ SRC_SCUERU0 Register를 통해 SCUERU0 SRN의 Interrupt를 Enable 한다.

External Interrupt Example

3. 프로그래밍

2) ERU를 설정하기 위한 함수를 구현한다.

```
// SCU Registers
#define SCU_BASE      (0xF0036000)
#define SCU_WDTSCON0  (*(volatile unsigned int*) (SCU_BASE + 0x0F0))
#define SCU_EICR1     (*(volatile unsigned int*) (SCU_BASE + 0x214))
#define SCU_IGCR0     (*(volatile unsigned int*) (SCU_BASE + 0x22C))

#define LCK            1
#define ENDINIT        0
#define INP0           12
#define EIEN0          11
#define FEN0           8
#define EXIS0          4
#define IGP0           14

// SRC Registers
#define SRC_BASE      (0xF0038000)
#define SRC_SCUERU0   (*(volatile unsigned int*) (SRC_BASE + 0xCD4))

#define TOS            11
#define SRE            10
#define SRPN           0
```

ERU 설정관련 레지스터 주소 및 비트 필드 정의

External Interrupt Example

3. 프로그래밍

2) ERU를 설정하기 위한 함수를 구현한다.

```
93 /* Initialize External Request Unit (ERU) */
94 void init_ERU(void)
95 {
96     /* ERU Input Channel 2 Setting */
97     /* Password Access to unlock WDTSCON0 */
98     ① SCU_WDTSCON0 = ((SCU_WDTSCON0 ^ 0xFC) & ~(1 << LCK)) | (1 << ENDINIT);
99     while((SCU_WDTSCON0 & (1 << LCK)) != 0);
100
101     // Modify Access to clear ENDINIT bit
102     SCU_WDTSCON0 = ((SCU_WDTSCON0 ^ 0xFC) | (1 << LCK)) & ~(1 << ENDINIT);
103     while((SCU_WDTSCON0 & (1 << LCK)) == 0);
104
105     ② SCU_EICR1 &= ~(0x7 << EXIS0);           // External input 1 is selected
106     SCU_EICR1 |= (0x1 << EXIS0);
107
108     ③ SCU_EICR1 |= (1 << FEN0);               // Falling edge enable
109
110     SCU_EICR1 |= (0x1 << EIEN0);             // The trigger event is enabled
111
112     ④ SCU_EICR1 &= ~(0x7 << INP0);           // An event from input ETL 2 triggers output OGU 0
113
114     ⑤ SCU_IGCR0 &= ~(0x3 << IGP0);           // IOUT(0) is activated in response to a trigger event
115     SCU_IGCR0 |= (0x1 << IGP0);             // The pattern is not considered
116
117     /* Password Access to unlock WDTSCON0 */
118     ⑥ SCU_WDTSCON0 = ((SCU_WDTSCON0 ^ 0xFC) & ~(1 << LCK)) | (1 << ENDINIT);
119     while((SCU_WDTSCON0 & (1 << LCK)) != 0);
120
121     /* Modify Access to set ENDINIT bit */
122     SCU_WDTSCON0 = ((SCU_WDTSCON0 ^ 0xFC) | (1 << LCK)) | (1 << ENDINIT);
123     while((SCU_WDTSCON0 & (1 << LCK)) == 0);
124
125     /* SRC Interrupt Setting For ECU */
126     ⑦ SRC_SCUERU0 &= ~(0xFF << SRPN);       // Set Priority : 0x0A
127     SRC_SCUERU0 |= (0x0A << SRPN);
128
129     ⑧ SRC_SCUERU0 &= ~(0x3 << TOS);         // CPU0 services
130
131     ⑨ SRC_SCUERU0 |= (1 << SRE);           // Service Request is enabled
132 }
```


External Interrupt Example

3. 프로그래밍

3) ERU를 통한 External Interrupt에 대한 ISR를 구현한다.

- ✓ 해당 함수가 ISR임을 나타내기 위해 컴파일러 지시자를 앞에 붙인다.
 - `__interrupt(PRIORITY)`: 괄호 안에는 ISR에 대응되는 Interrupt의 우선순위를 입력한다.
 - `__vector_table(CPU_NUM)`: 괄호 안에는 해당 ISR을 수행하는 CPU 번호를 입력한다.
- ✓ ISR이 수행된 후, 해당 Interrupt Flag가 자동으로 Clear 되기 때문에 이를 위한 코드가 필요하지 않다.

```
158  __interrupt(0x0A) __vector_table(0)
159  void ERU0_ISR(void)
160  {
161      PORT10_OMR |= ((1<<PCL1) | (1<<PS1));           // Toggle LED RED
162  }
```

ERU0 Interrupt Service Routine

External Interrupt Example

3. 프로그래밍

4) 동작에 따라 'main' 함수를 구현한다.

```
32 /* Define PORT10 Registers for LED */
33 #define PORT10_BASE (0xF003B000)
34 #define PORT10_IOCR0 (*(volatile unsigned int*)(PORT10_BASE + 0x10))
35 #define PORT10_OMR (*(volatile unsigned int*)(PORT10_BASE + 0x04))
36
37 #define PC1 11
38 #define PCL1 17
39 #define PS1 1
40
41 /* Define PORT02 Registers for Switch2 */
42 #define PORT02_BASE (0xF003A200)
43 #define PORT02_IOCR0 (*(volatile unsigned int*)(PORT02_BASE + 0x10))
44 #define PORT02_IN (*(volatile unsigned int*)(PORT02_BASE + 0x24))
45
46 #define PC1 11
47 #define P1 1
48
49 /* Define SCU Registers for Interrupt */
50 #define SCU_BASE (0xF0036000)
51 #define SCU_WDTSCON0 (*(volatile unsigned int*)(SCU_BASE + 0x0F0))
52 #define SCU_EICR1 (*(volatile unsigned int*)(SCU_BASE + 0x214))
53 #define SCU_IGCR0 (*(volatile unsigned int*)(SCU_BASE + 0x22C))
54
55 #define LCK 1
56 #define ENDINIT 0
57 #define INP0 12
58 #define EIEN0 11
59 #define FEN0 8
60 #define EXIS0 4
61 #define IGP0 14
62
63 /* Define SRC Registers for Interrupt */
64 #define SRC_BASE (0xF0038000)
65 // #define SRC_SCUERU0 (*(volatile unsigned int*)(SRC_BASE + 0xCD4))
66
67 #define TOS 11
68 #define SRE 10
69 #define SRPN 0
70
71 IfxCpu_syncEvent g_cpuSyncEvent = 0;
```

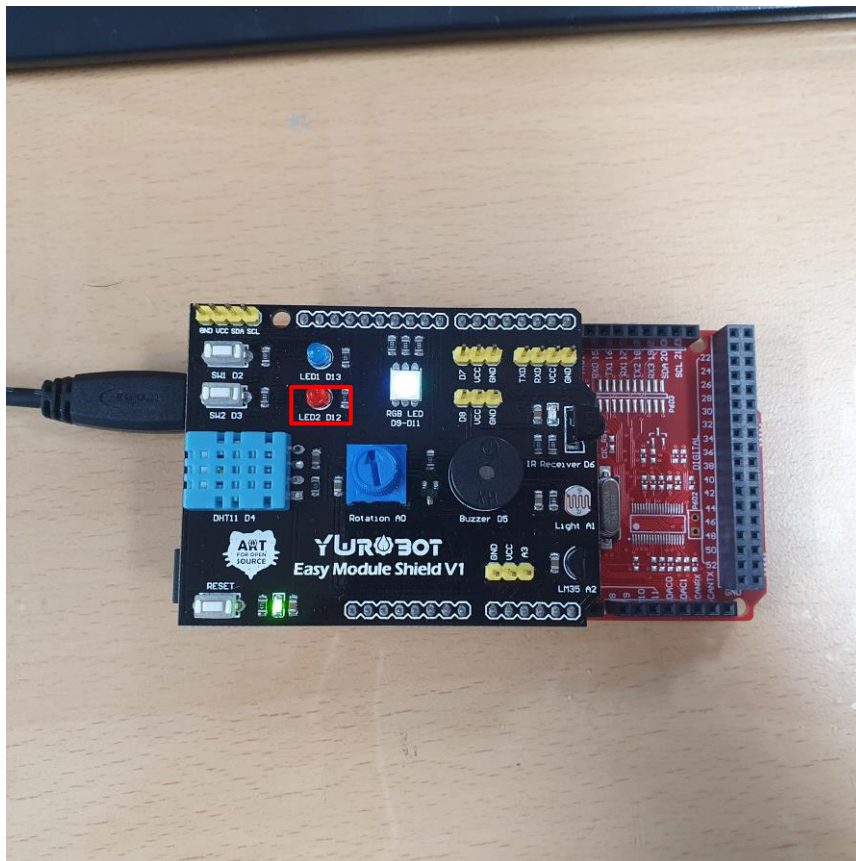
```
134 int core0_main(void)
135 {
136     IfxCpu_enableInterrupts();
137
138     /* !!WATCHDOG0 AND SAFETY WATCHDOG ARE DISABLED HERE!!
139      * Enable the watchdogs and service them periodically if it is required
140      */
141     IfxScuWdt_disableCpuWatchdog(IfxScuWdt_getCpuWatchdogPassword());
142     IfxScuWdt_disableSafetyWatchdog(IfxScuWdt_getSafetyWatchdogPassword());
143
144     /* Wait for CPU sync event */
145     IfxCpu_emitEvent(&g_cpuSyncEvent);
146     IfxCpu_waitEvent(&g_cpuSyncEvent, 1);
147
148     init_ERU(); // Initialize ERU
149     init_LED(); // Initialize LED
150     init_Switch(); // Initialize Switch
151
152     while(1)
153     {
154     }
155     return (1);
156 }
157
158 __interrupt(0x0A) __vector_table(0)
159 void ERU0_ISR(void)
160 {
161     PORT10_OMR |= ((1<<PCL1) | (1<<PS1)); // Toggle LED RED
162 }
163
```

- ✓ '_enable()'을 통해 CPU의 Global Interrupt Enable을 수행한다.
- ✓ 앞서 구현한 함수들을 호출한다.

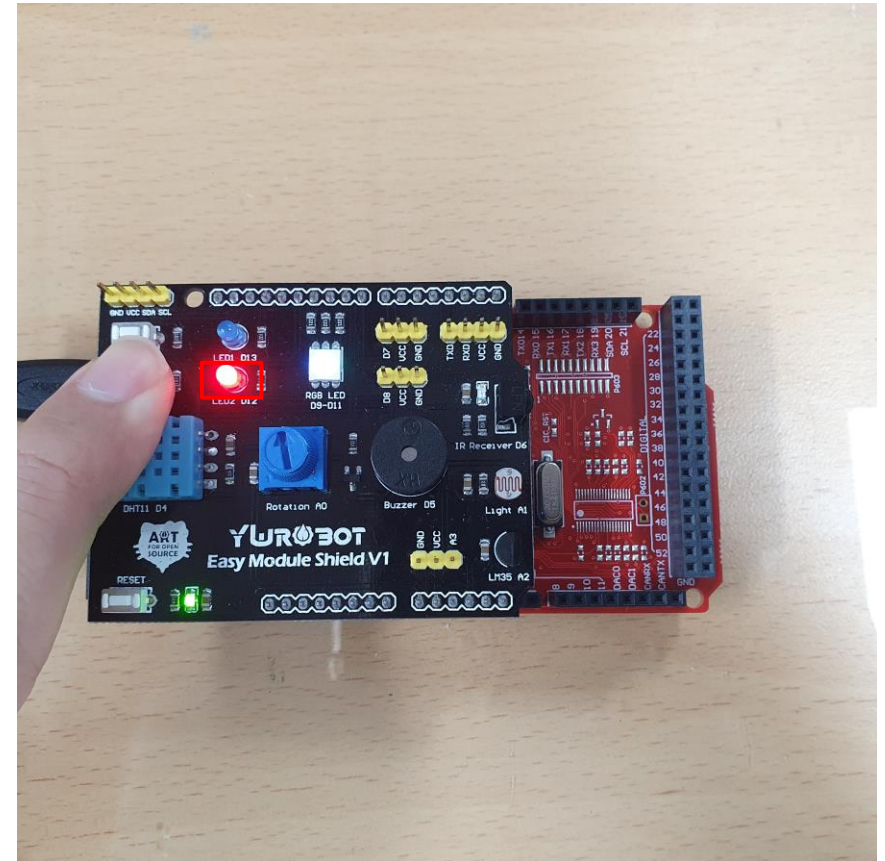
External Interrupt Example

4. 동작 확인

- ✓ Build 및 Debug 후 ('Resume' 버튼 클릭), Switch를 누를 때마다 LED가 Toggle 되는 것을 확인한다.



Switch
Click!
⇕

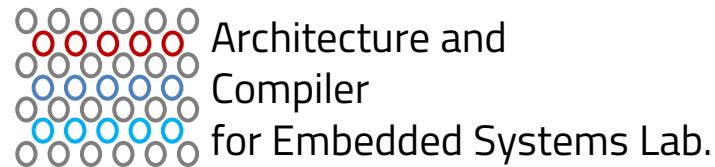


실습

1. Reference Code 동작 확인
2. 신규 C 파일로 External Interrupt Setting 작성
3. Key PUSH시 동작 말고, Release 할때 동작하도록 구현
4. KEY1, 2 모두 Push 일때 External Interrupt 동작
Key1 PUSH : RED LED Toggle
KEY2 PUSH : BLUE LED Toggle

Q & A

Thank you for your attention



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