1. OVERVIEW

The SM3414 is a reflective absolute linear optical encoder module. The absolute code pattern on the scale is read optically and then output via a serial interface.

An analog incremental signal can also be output.

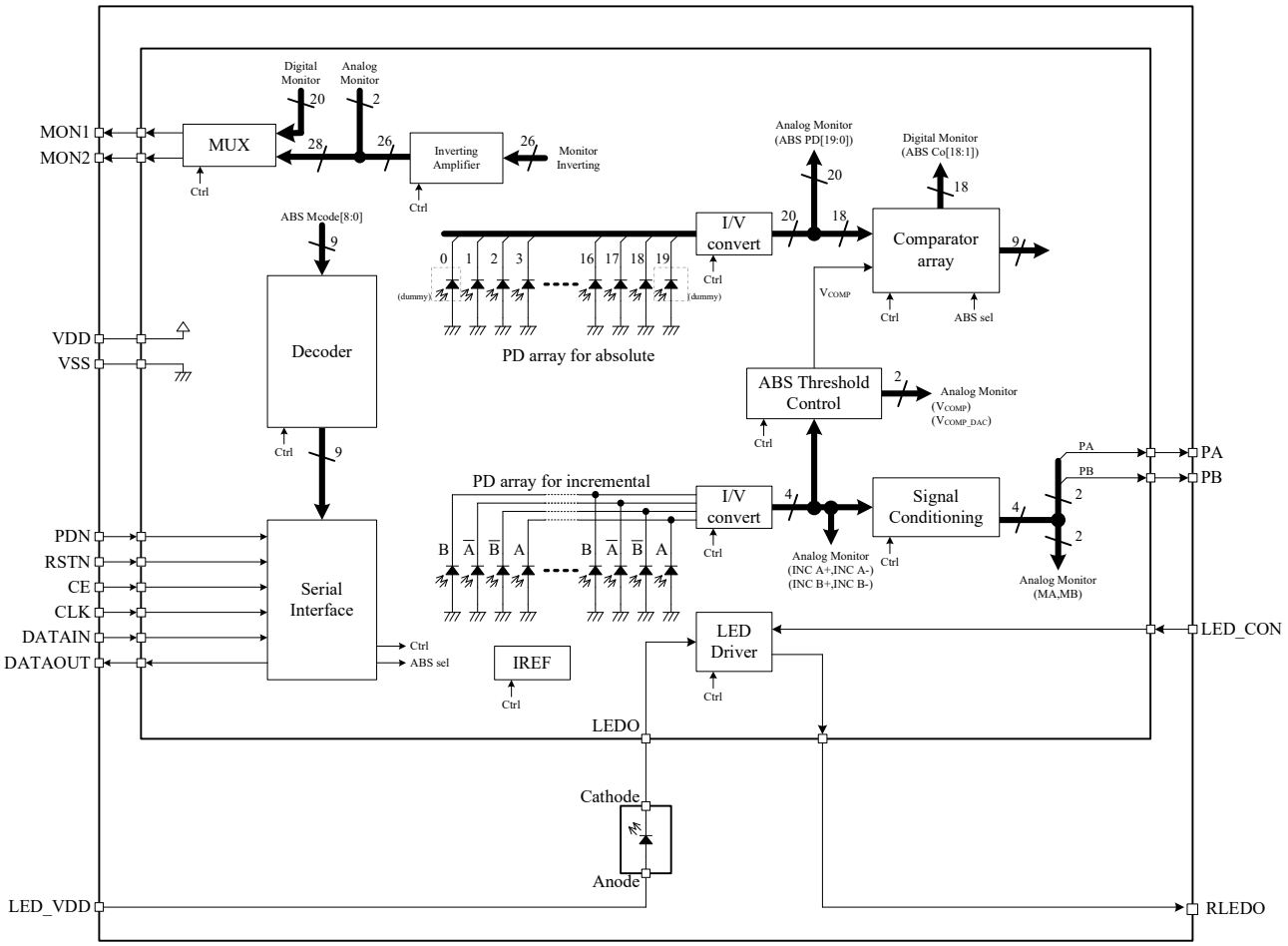
The device incorporates various adjustment circuits controlled via the serial interface, including adjustments for the absolute code binarization threshold voltage and the incremental signal I/V conversion gain.

* The following abbreviations are used in this document.
Absolute: ABS, Incremental: INC, Photodiode: PD, Serial interface: SIF

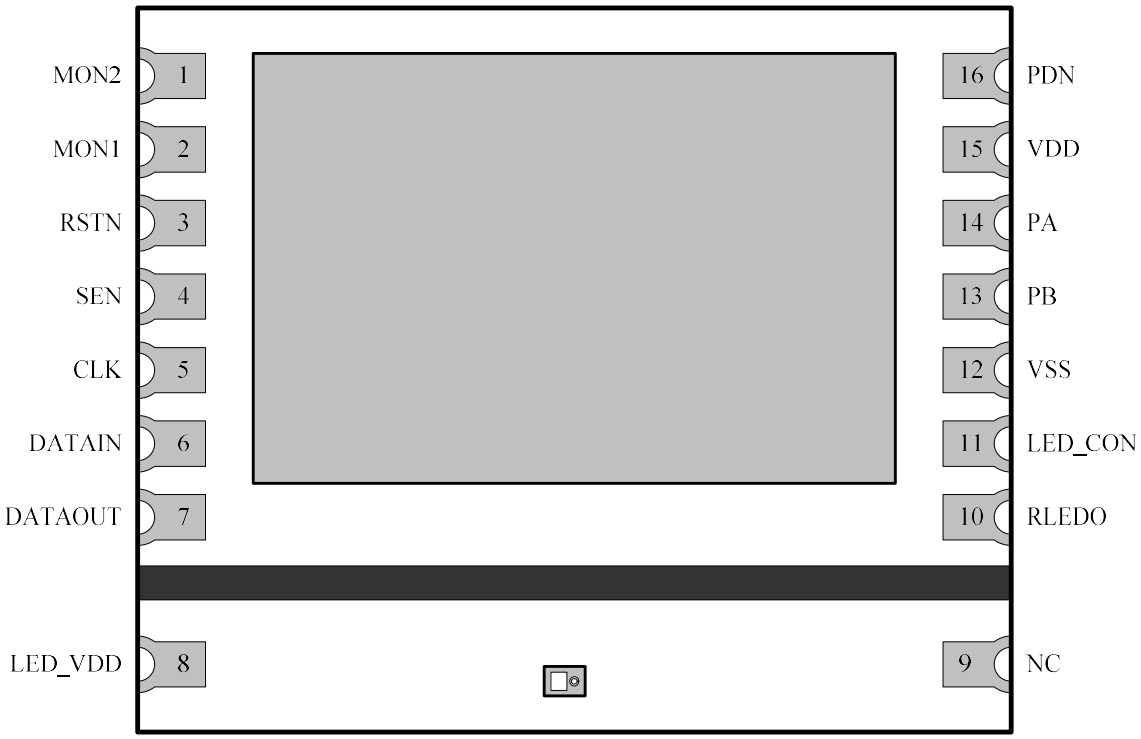
2. FEATURES

- ■ Supply voltage : 2.7 to 3.3V
- ■ Current consumption : 8mA (including 5mA LED current, typ. conditions)
- ■ Operating temperature range : -30 to +70°C
- ■ Absolute output : 51.2mm scale length, 100□m resolution (9-bit serial output), built-in decoder
- ■ Incremental outputs : Analog phase A and phase B
- ■ Built-in adjustment circuits : Absolute binarization voltage adjustment, Incremental signal gain adjustment
- ■ LED wavelength : 850nm (typ.)
- ■ Logic input 3.6V input-tolerant function
- ■ Low-crosstalk dedicated process
- ■ Photodiode with built-in antireflection film

3. BLOCK DIAGRAM



4. PIN LAYOUT



TOP View

5. PIN DESCRIPTION

Pin No.	Name	Type	Description
1	MON2	O	Internal signal monitor output pin 2
2	MON1	O	Internal signal monitor output pin 1
3	RSTN	I	Register reset and power-down pin (Pull-down pin, Active-Low)
4	SEN	I	Serial interface enable signal (Pull-up pin, Active-Low)
5	CLK	I	Serial interface clock signal input pin
6	DATAIN	I	Serial interface data input pin
7	DATAOUT	O	Serial interface data output pin
8	LED_VDD	S	LED power supply pin
9	NC	-	No connection
10	RLEDO	O	LED current control resistor connection pin
11	LED_CON	I	LED current adjustment pin
12	VSS	S	Ground pin
13	PB	O	Incremental signal phase B output pin
14	PA	O	Incremental signal phase A output pin
15	VDD	S	Power supply pin
16	PDN	I	Absolute function power-down pin (Pull-down pin, Active-Low)

[Type] I: Input pin, O: Output pin, S: Power supply pin

6. ABSOLUTE MAXIMUM RATINGS

V_{SS}=0V

Parameter	Symbol	Conditions	Rating	Unit	Note
Supply voltage	V_{DD}	VDD, LED_VDD pins	-0.3 to 5.0	V	*1
Input voltage	V_{IN_D}	SEN, CLK, DATAIN, RSTN, PDN pins	-0.3 to 5.0	V	*1
	V_{IN_A}	LED_CON pin	-0.3 to V_{DD}+0.3	V	*1,*2
Output voltage	V_{OUT}	PA, PB, MON1, MON2, RLEDO, DATAOUT pins	-0.3 to V_{DD}+0.3	V	*1,*2
LED forward current	I_{LED}	LED_VDD pin	30	mA	
Junction temperature	T_J		125	°C	*3
Storage temperature	T_{STG}		-40 to 85	°C	*4

*1: Parameters must not exceed ratings, not even momentarily. If a rating is exceeded, there is a risk of adverse effect on electrical characteristics and reliability.

*2: "V_{DD}" in absolute maximum ratings refers to the recommended operating conditions supply voltage value (V_{DD}).

*3: Use within the rated range. If a rating is exceeded, there is a risk of deterioration in characteristics and decrease in reliability.

*4: Stored separately in Nitrogen (N_2) atmosphere or vacuum.

7. RECOMMENDED OPERATING CONDITIONS

V_{SS}=0V

Parameter	Symbol	Conditions	MIN	TYP	MAX	Unit
Supply voltage	V_{DD}	Between VDD and VSS pins	2.7	3.0	3.3	V
LED supply voltage	V_{LVDD}	Between LED_VDD and VSS pins	2.7	3.0	3.6	V
Logic input voltage	V_{IN_D}	SEN, CLK, DATAIN, RSTN, PDN pins	V_{SS}	-	3.6	V
Analog input voltage	V_{IN_A}	LED_CON pin	V_{SS}	-	V_{DD}	V
LED current	I_{LED}		-	5	20	mA
Operating temperature	T_a		-30	-	70	°C

* Operation outside the recommended operating conditions may adversely affect reliability. Use only within specified ratings.

8. ELECTRICAL CHARACTERISTICS

8.1. DC Characteristics

V_{DD}=V_{LVDD}=3.0V, V_{SS}=0V, T_a=25°C unless otherwise noted

Parameter	Symbol	Conditions	MIN	TYP	MAX	Unit
Current consumption 1	I_{DD1}	No output load, RSTN=PDN=SEN=V_{DD}, CLK=DATAIN=V_{SS}, V_{LVDD} = V_{SS} *INC/ABS operation, when not accessing SIF	-	3.0	8.5	mA
Current consumption 2	I_{DD2}	No output load, RSTN=SEN=V_{DD}, CLK=DATAIN=PDN=V_{SS}, V_{LVDD} = V_{SS} *INC operation, ABS stopped, when not accessing SIF	-	2.5	7.0	mA
Standby-mode current consumption	I_{NOP}	No output load, CLK=DATAIN=RSTN=PDN= V_{SS}, SEN= V_{DD} V_{LVDD} = V_{SS}	-	-	5.0	µA
High-level logic input voltage	V_{IH}	RSTN, SEN, CLK, DATAIN, PDN pins	V_{DD}-0.7	-	3.6	V
Low-level logic input voltage	V_{IL}		0	-	0.3	V
High-level logic input current	I_{IH1}	V_{IN}=3.6V, SEN pin	-	6	50	µA
	I_{IH2}	V_{IN}=3.6V, CLK, DATAIN pins	-	-	1	µA
	I_{IH3}	V_{IN}=3.6V, RSTN, PDN pins	-	15	100	µA
Low-level logic input current	I_{IL1}	V_{IN}=V_{SS}, RSTN, PDN, CLK, DATAIN pins	-1	-	-	µA
	I_{IL2}	V_{IN}= V_{SS}, SEN pin	-100	-30	-	µA
High-level logic output voltage	V_{OH}	DATAOUT pin, I_{OUT}=1mA	V_{DD}-0.5	-	V_{DD}	V
Low-level logic output voltage	V_{OL}	DATAOUT, I_{OUT}=-1mA	0	-	0.5	V

8.2. Analog Circuit Electrical Characteristics

V_{DD}=V_{LVDD}=3.0V, V_{SS}=0V, T_a=25°C, using NPC reference scale, unless otherwise stated

Parameter	Symbol	Conditions	MIN	TYP	MAX	Unit
Incremental signal output frequency range	f_{OUT}	PA, PB pins, 50pF load capacitance, 100µm incremental signal cycle time	-	-	10	kHz
Incremental signal output signal amplitude	V_{APP}	PA, PB pins, 100kΩ load resistance (R), I_{LED}: 5mA (R_{LED}=100Ω, V_{LED_CON}=0.5V) I/V conversion gain: 1 (register GA,GB[2:0]=0h *1), D_{YAW}=0, D_{PTCH}=0, D_{ROL}=0, D_{CNTR}=0, D_{GAP}=0	0.18	0.35	0.70	V_{P-P}

*1: See "9.12.7. Incremental Phase A/Phase B I/V conversion gain setting register (GAB[2:0])."

8.3. Mounting Tolerance*2

V_{DD}=V_{LVDD}=3.0V, V_{SS}=0V, T_a=25°C, using NPC reference scale, unless otherwise noted

Parameter	Symbol	Conditions	MIN	TYP	MAX	Unit
Azimuth offset (Yaw)	D_{YAW}	Excluding dynamic fluctuations	-1.0	0	1.0	deg
		Dynamic fluctuations only	-0.15	0	0.15	deg
Pitch offset	D_{PTCH}		-1.0	0	1.0	deg
Roll offset	D_{ROL}		-1.0	0	1.0	deg
Center offset	D_{CNTR}	Including dynamic fluctuations	-0.2	0	0.2	mm
Gap offset	D_{GAP}	Gap=2.13mm (reference)*3, Excluding dynamic fluctuations	-0.1	0	0.6	mm
		Initial position (reference), dynamic fluctuations only	-0.25	0	0.25	mm

*2: These parameters are guaranteed by design. Not tested prior to shipping.
*3: The gap is the distance between the package surface and the scale.

For the definition of tolerance, see "14.1. Mounting Tolerance Definition."

9. FUNCTIONAL DESCRIPTION

9.1. Absolute Signal Output Function

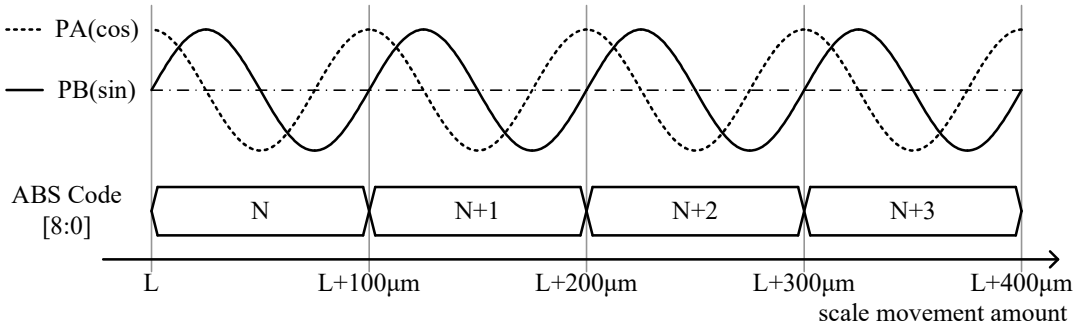
The SM3414 optically reads the reflection/non-reflection pattern from an absolute code on an external scale, decodes the M code to a binary code, and then digitally outputs the absolute signal as 9-bit data over a serial interface. The 9-bit output code can also be output as raw M code without decoding.

The absolute code has a single code assigned to each scale deviation of 100µm, which results in a maximum amount of displacement that can be measured of 51.2mm.

9.2. Incremental Signal Output Function

The SM3414 optically reads the reflection/non-reflection pattern for an incremental signal pattern from an external scale, and outputs a two-phase analog signal with a phase difference of 90 degrees from the PA and PB pins. The output sine waves are output with $0.5V_{DD}$ DC bias and an amplitude that varies with the detected light level.

One cycle of the incremental signal corresponds to a displacement of 100µm on the scale.

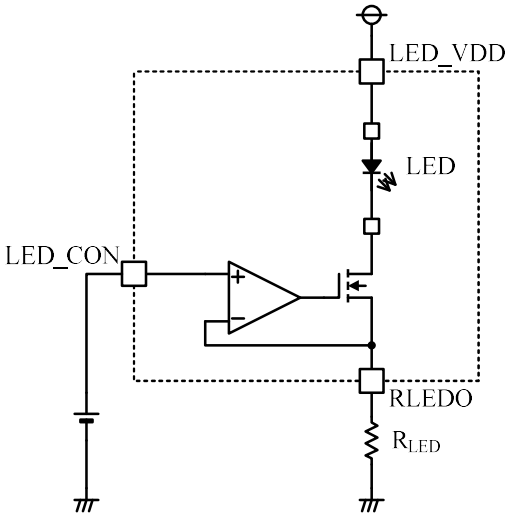


9.3. LED Current Adjustment Function

The SM3414 has a built-in LED element and LED driver, and the LED current can be adjusted by varying the voltage applied to the LED_CON pin and the resistance connected to the RLEDO pin.

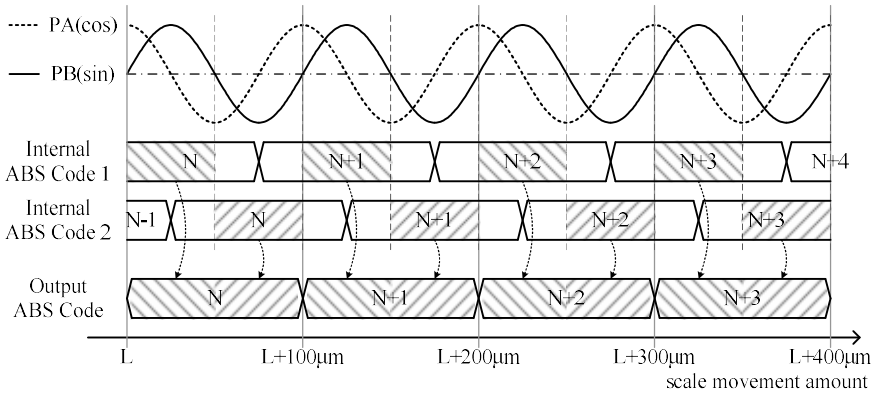
In addition, the LED_VDD supply voltage is provided separately from the VDD pin. If the LED was driven from only the V_{DD} voltage, the LED current control range is reduced by the forward voltage V_F across the LED. However, a voltage higher than V_{DD} can be applied to the LED_VDD pin to alleviate this problem.

$$\text{LED current } [A] = \frac{\text{LED\_CON voltage } [V]}{\text{RLED } [\Omega]}$$



9.4. Absolute Signal, Phase Select Function

The SM3414 receives the reflected light of 1-bit absolute code as an “internal ABS code 1” and “internal ABS code 2” using two 0.5-bit wide photodiodes. By selecting either “internal ABS code 1” or “internal ABS code 2” in realtime depending on the state of the incremental signal, it is possible to obtain a stable output by avoiding the region where the photodiode output is unstable while it is transitioning to the next code.



ABS code selection

To read ABS codes:

- Select internal ABS code 1 when PB is High.
- Select internal ABS code 2 when PB is Low.

“Internal ABS code 1” is a code in which 1-bit wide light of ABS code reflected from the scale is detected by a 0.5-bit wide photodiode on the LSB side, and “internal ABS code 2” is a code in which 1-bit wide light of ABS code reflected from the scale is detected by a 0.5-bit wide photodiode on the MSB side.

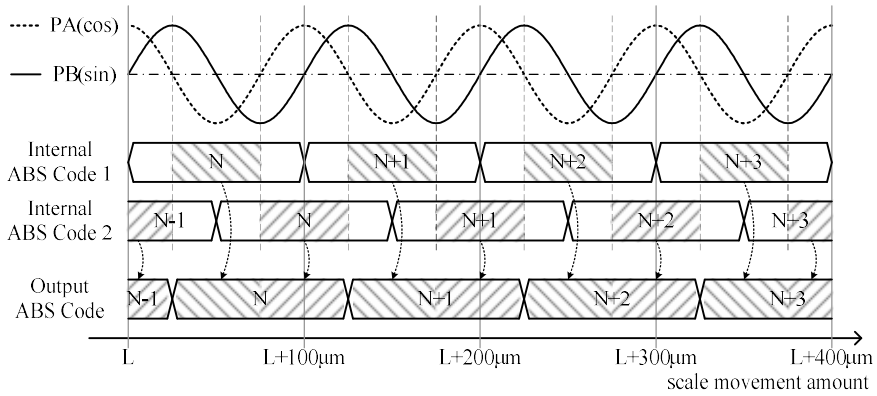
Stable output can be obtained by selecting and reading “Internal ABS code 1” when the PB component of the incremental signal is higher than the midpoint potential, and “Internal ABS code 2” when the PB component is lower than the midpoint potential.

In the arrangement above, if the phase relationship between the absolute signal and incremental signal is offset due to a physical offset in the mounting positions of the SM3414 and the scale (an offset of ±90° or more for an incremental cycle of 360° in the figure above[*1]), only the unstable range will be output instead of the intended function.

To avoid this, it is necessary to select and read the internal ABS codes according to the offset, considering the phase information of the incremental signal.

The phases in the following diagram are represented as PA=+cos and PB=+sin, and 0° is defined as the point at which PA is a maximum voltage and the PB voltage is $0.5V_{DD}$.

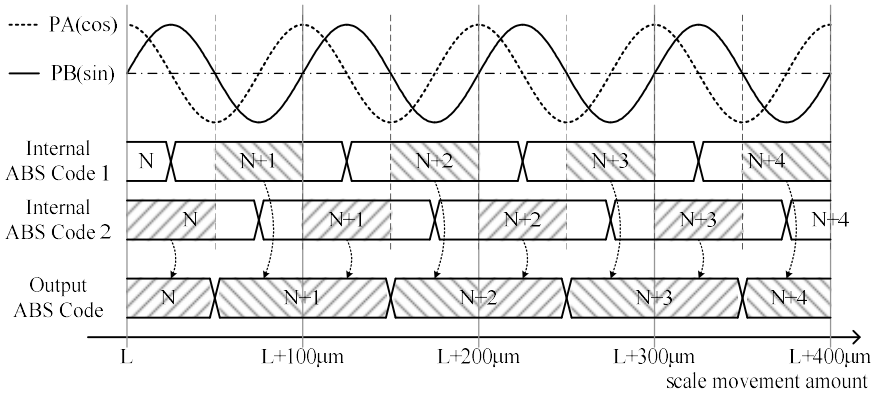
*1 The center distance between the absolute photodiode (ABS PD) and the incremental photodiode (INC PD) is 2700µm. When the azimuth (D_{YAW}) is 1°, the offset in the vertical direction between ABS PD and INC PD is approximately 47.1 µm $(2700 \times \tan 1° \approx 47.1\,\mu m)$. Since one INC PD cycle displacement is 200µm, the phase offset between the ABS signal and INC signal becomes approximately 90°.



ABS code selection when the phase offset is 90°

To read ABS codes:

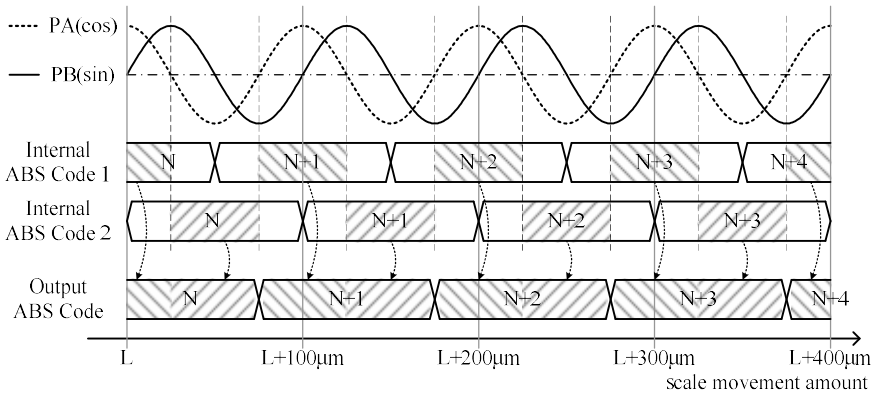
- Select internal ABS code 1 when PA is Low.
- Select internal ABS code 2 when PA is High.



ABS code selection when the phase offset is -180°

To read ABS codes:

- Select internal ABS code 1 when PB is Low.
- Select internal ABC code 2 when PB is High.



ABS code selection when the phase offset is -90°

To read ABS codes:

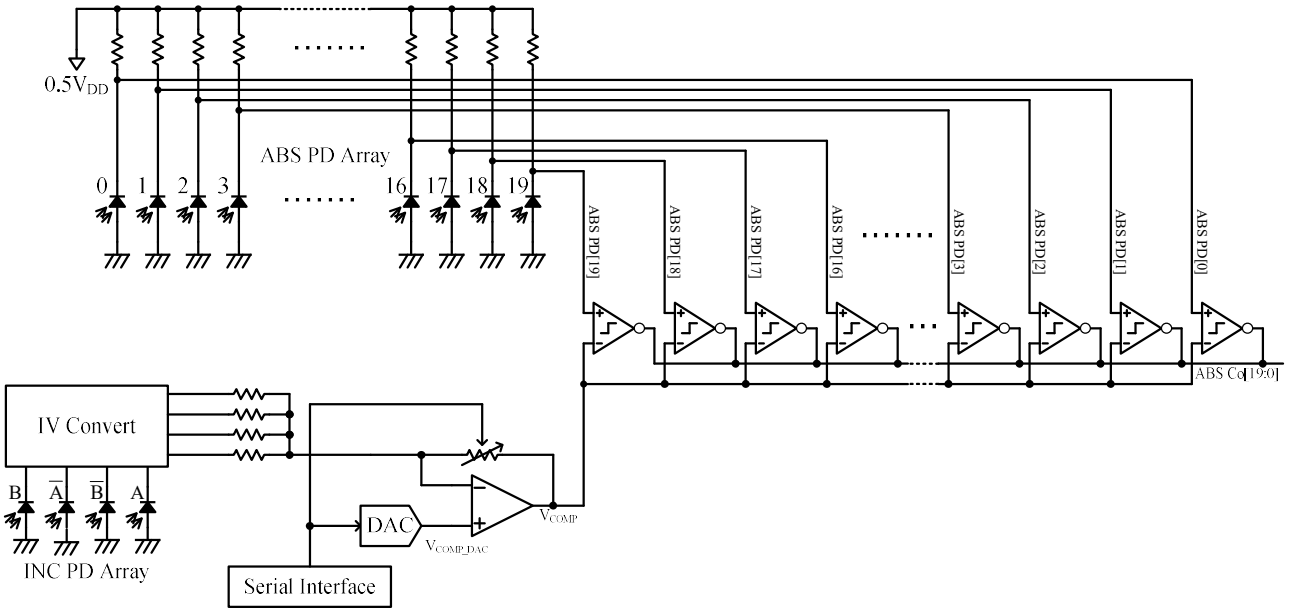
- Select internal ABS code 1 when PA is High.
- Select internal ABS code 2 when PA is Low.

9.5. Absolute Binarization Voltage Adjustment Function

The SM3414 has a built-in function that tracks the amount of light received by the photodiode by converting the analog absolute signal to binary using a threshold voltage in order to read the absolute code in a stable manner.

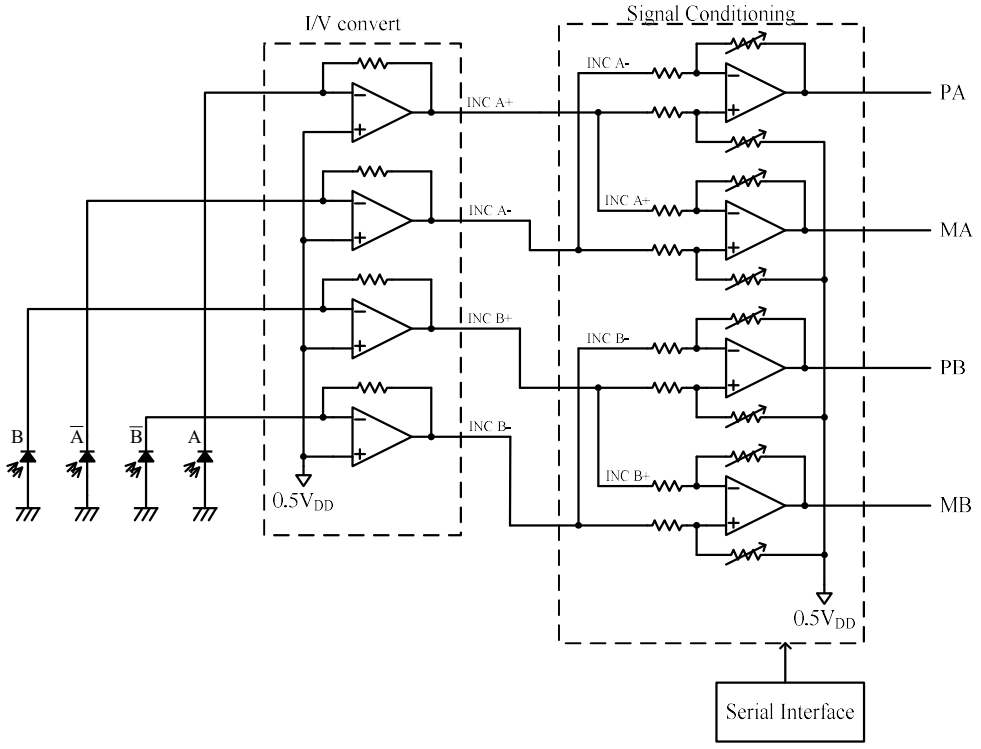
The photodiode for the incremental signal is used to detect the amount of light.

The gain setting (which determines the change in the binarization threshold voltage corresponding to changes in the amount of light) and the DC offset voltage (which serves as the reference for changes in the binarization threshold voltage) are adjusted using the serial interface.



9.6. Incremental Output, I/V Conversion Gain Adjustment Function

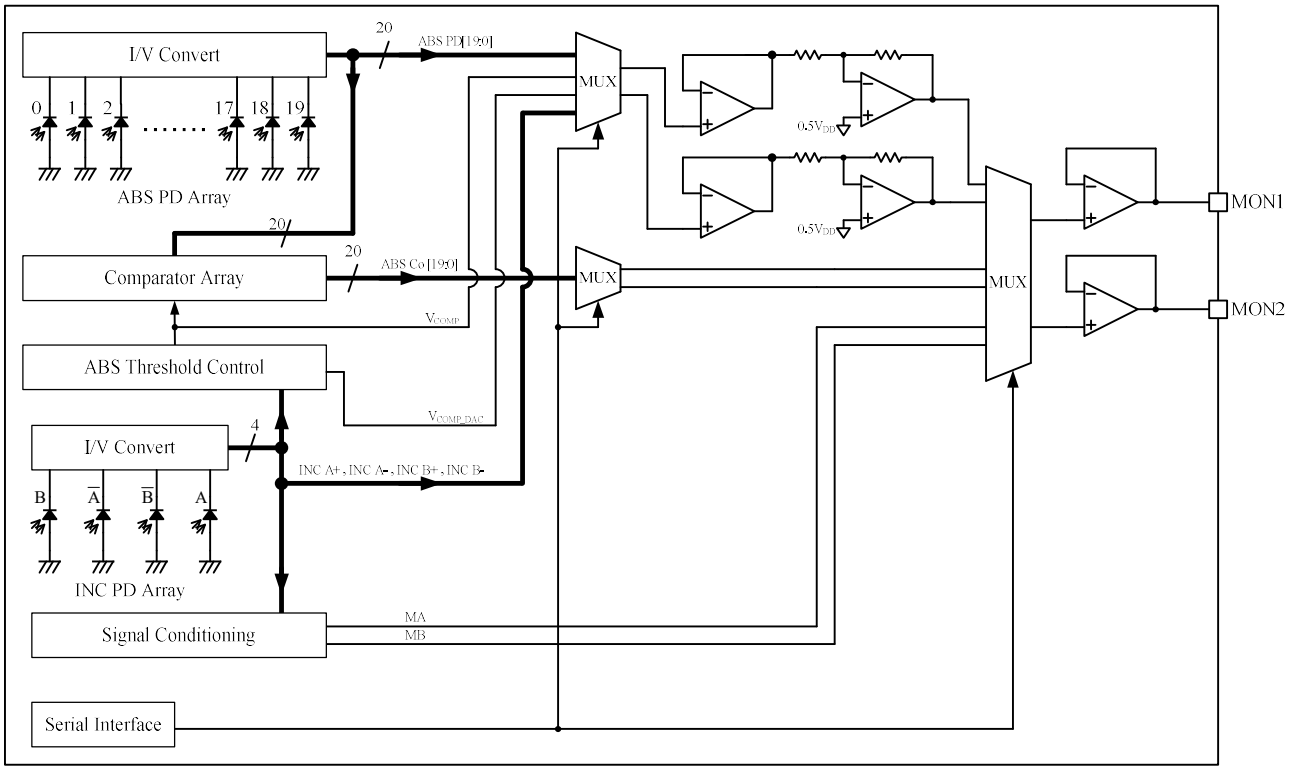
The SM3414 can adjust the I/V conversion gain of the incremental signal. The gain adjustment value is adjusted using the serial interface. The adjustment value can be set individually for phase A and phase B.



9.7. Internal Signal Monitor Function

The SM3414 has a built-in function for monitoring various internal signals in order to check the signals inside the IC. Signals that can be monitored include the analog signal prior to binarization of each bit of the absolute signal, the binarization threshold voltage, and the internal signals after I/V conversion of the incremental signal.

The signals to monitor are set using the serial interface, and are output from the MON1 and MON2 pins. For details about the signals to monitor and the output pins, see "9.12.8. Monitor target signal setting register (MON_SEL[3:0]" and "9.12.9. Monitor target signal setting register 2 (OUT_SEL1[4:0], OUT_SEL2[4:0]."



9.8. Reset Function

You can reset all the SM3414 shift register contents in the serial interface to "0" by setting the RSTN pin to Low level. During normal operation, set the RSTN pin to High level.

9.9. Absolute Circuit Power-Down Function

When the PDN pin is set to Low level, the circuit functionality for the absolute signal stops, and only the circuit for the incremental signal is in the operating state, enabling the current consumption to be reduced.

9.10. Standby Function

When both the PDN pin and RSTN pin are set to Low level, the device switches to standby mode and all circuits stop, including the LED driver. In standby mode, the current consumption is reduced to an extremely low value.

9.11. M Code Conversion Function

The SM3414 uses a built-in decoder to convert M codes to binary data.

[M-code conversion table]

Binary	M Code	Binary	M Code	Binary	M Code	Binary	M Code
0	0	48	84	96	19	144	476
1	1	49	168	97	38	145	440
2	2	50	337	98	76	146	368
3	4	51	163	99	153	147	225
4	8	52	326	100	307	148	450
5	17	53	141	101	103	149	389
6	34	54	283	102	206	150	267
7	68	55	54	103	413	151	22
8	136	56	108	104	314	152	44
9	273	57	217	105	116	153	89
10	35	58	435	106	232	154	179
11	70	59	359	107	465	155	358
12	140	60	207	108	419	156	205
13	281	61	415	109	327	157	411
14	50	62	318	110	143	158	310
15	100	63	124	111	287	159	109
16	200	64	249	112	62	160	219
17	401	65	499	113	125	161	439
18	291	66	487	114	251	162	367
19	71	67	463	115	503	163	222
20	142	68	414	116	495	164	445
21	285	69	316	117	478	165	378
22	58	70	120	118	444	166	244
23	117	71	241	119	376	167	488
24	234	72	482	120	240	168	464
25	469	73	453	121	480	169	417
26	427	74	395	122	449	170	323
27	342	75	278	123	387	171	135
28	173	76	45	124	263	172	270
29	347	77	91	125	15	173	28
30	182	78	183	126	31	174	57
31	364	79	366	127	63	175	115
32	216	80	220	128	127	176	230
33	433	81	441	129	255	177	460
34	355	82	370	130	511	178	408
35	199	83	229	131	510	179	304
36	398	84	458	132	508	180	97
37	284	85	404	133	504	181	194
38	56	86	297	134	496	182	388
39	113	87	82	135	481	183	265
40	226	88	164	136	451	184	18
41	452	89	328	137	391	185	36
42	393	90	144	138	271	186	72
43	274	91	288	139	30	187	145
44	37	92	65	140	61	188	290
45	74	93	130	141	123	189	69
46	149	94	260	142	247	190	138
47	298	95	9	143	494	191	277

Binary	M Code
192	43
193	87
194	174
195	349
196	186
197	373
198	235
199	471
200	431
201	350
202	188
203	377
204	242
205	484
206	457
207	402
208	293
209	75
210	151
211	302
212	92
213	185
214	371
215	231
216	462
217	412
218	312
219	112
220	224
221	448
222	385
223	259
224	7
225	14
226	29
227	59
228	119
229	238
230	477
231	442
232	372
233	233

Binary	M Code
234	467
235	423
236	335
237	158
238	317
239	122
240	245
241	490
242	468
243	425
244	338
245	165
246	330
247	148
248	296
249	80
250	160
251	320
252	129
253	258
254	5
255	10
256	21
257	42
258	85
259	170
260	341
261	171
262	343
263	175
264	351
265	190
266	381
267	250
268	501
269	491
270	470
271	429
272	346
273	180
274	360
275	208

Binary	M Code
276	416
277	321
278	131
279	262
280	13
281	27
282	55
283	110
284	221
285	443
286	374
287	237
288	475
289	438
290	365
291	218
292	437
293	363
294	214
295	428
296	344
297	176
298	352
299	193
300	386
301	261
302	11
303	23
304	46
305	93
306	187
307	375
308	239
309	479
310	446
311	380
312	248
313	497
314	483
315	455
316	399
317	286

Binary	M Code
318	60
319	121
320	243
321	486
322	461
323	410
324	308
325	105
326	211
327	422
328	333
329	154
330	309
331	107
332	215
333	430
334	348
335	184
336	369
337	227
338	454
339	397
340	282
341	52
342	104
343	209
344	418
345	325
346	139
347	279
348	47
349	95
350	191
351	383
352	254
353	509
354	506
355	500
356	489
357	466
358	421
359	331

Binary	M Code
360	150
361	300
362	88
363	177
364	354
365	197
366	394
367	276
368	41
369	83
370	166
371	332
372	152
373	305
374	99
375	198
376	396
377	280
378	48
379	96
380	192
381	384
382	257
383	3
384	6
385	12
386	25
387	51
388	102
389	204
390	409
391	306
392	101
393	202
394	405
395	299
396	86
397	172

Binary	M Code
398	345
399	178
400	356
401	201
402	403
403	295
404	79
405	159
406	319
407	126
408	253
409	507
410	502
411	493
412	474
413	436
414	361
415	210
416	420
417	329
418	146
419	292
420	73
421	147
422	294
423	77
424	155
425	311
426	111
427	223
428	447
429	382
430	252
431	505
432	498
433	485
434	459
435	406

Binary	M Code
436	301
437	90
438	181
439	362
440	212
441	424
442	336
443	161
444	322
445	133
446	266
447	20
448	40
449	81
450	162
451	324
452	137
453	275
454	39
455	78
456	157
457	315
458	118
459	236
460	473
461	434
462	357
463	203
464	407
465	303
466	94
467	189
468	379
469	246
470	492
471	472
472	432
473	353

Binary	M Code
474	195
475	390
476	269
477	26
478	53
479	106
480	213
481	426
482	340
483	169
484	339
485	167
486	334
487	156
488	313
489	114
490	228
491	456
492	400
493	289
494	67
495	134
496	268
497	24
498	49
499	98
500	196
501	392
502	272
503	33
504	66
505	132
506	264
507	16
508	32
509	64
510	128
511	256

9.12. Serial Interface Function

The SM3414 employs a built-in serial interface for reading and writing registers for saving constant settings and parameters of each circuit.

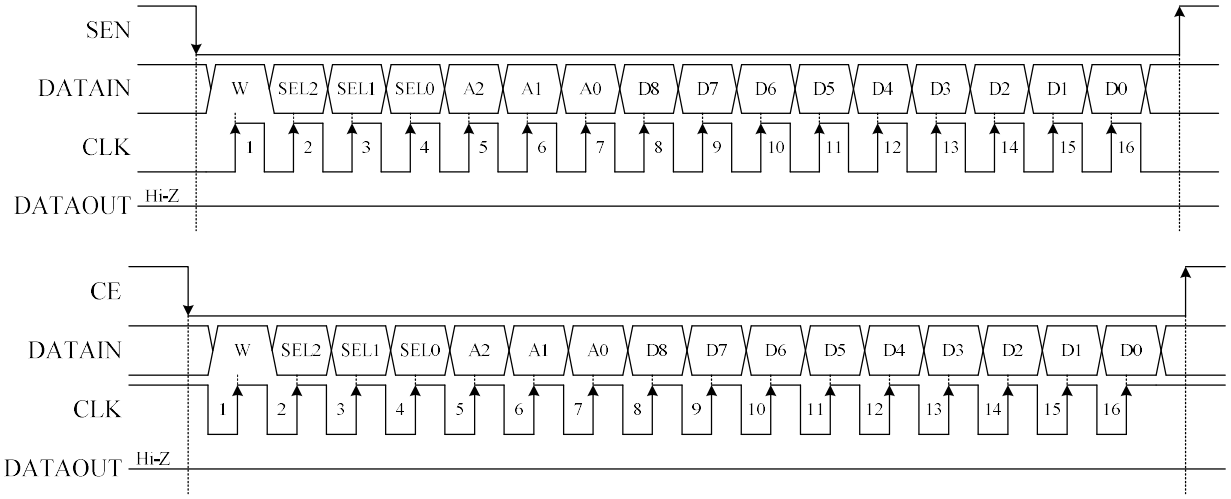
When the SEN pin input is set to Low level, serial interface operation starts. The SM3414 serial interface supports SPI mode 0 and mode 3.

9.12.1. Writing register data

When the SEN pin input is set to Low level, serial interface operation starts.

Send a 1-bit R/W mode setting bit (High level for write mode), a 3-bit absolute PD assignment, and a 3-bit write address assignment to the DATAIN pin, followed by 9-bit write data with the MSB first. On the 16th falling edge on the CLK pin, the write data is loaded into the device and the data becomes active.

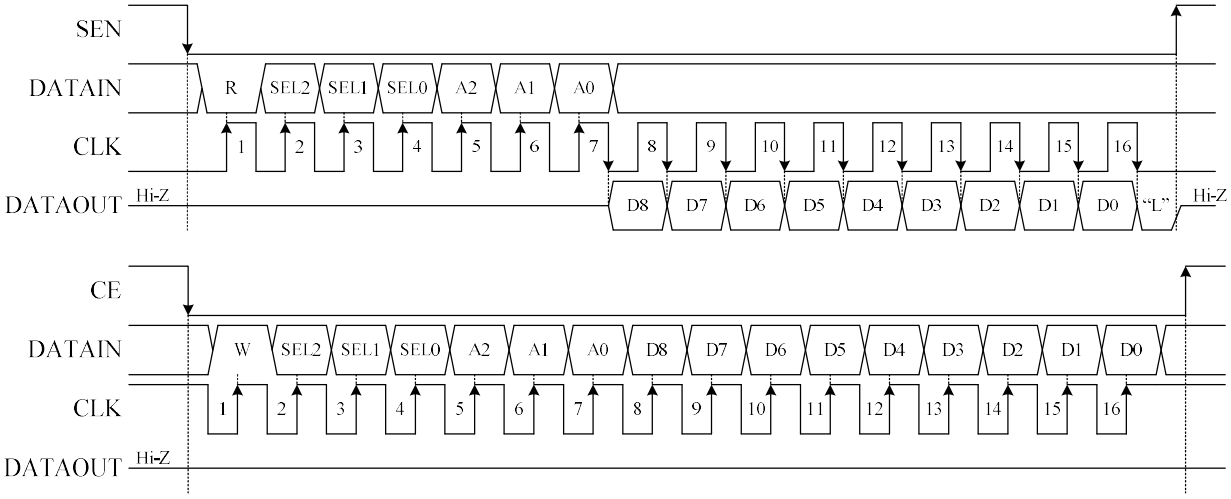
Note that when writing to the registers, do not apply any number of clock cycles other and 16 to the CLK pin. If a different number of cycles is input, it may cause an error in writing.



9.12.2. Reading register data

When the SEN pin input is set to Low level, serial interface operation starts.

Send a 1-bit R/W mode setting bit (Low level for read mode), a 3-bit absolute PD assignment, and a 3-bit read address assignment to the DATAIN pin, and then read the 9-bit data output from the DATAOUT pin with the MSB first starting from the 7th falling edge on the CLK pin. After the 16th falling edge on the CLK pin, the output goes Low level, and serial interface operation ends when a rising edge occurs on the SEN pin.



9.12.3. Internal register map

Definition	R/W	SEL [2:0]	Address [2:0]	D[8:0]									Default value
				D8	D7	D6	D5	D4	D3	D2	D1	D0	
ABS output data	R	*00	000	ABS_DATA[8:0] (Even-numbered PD select, decode output)									-
		*01		ABS_DATA[8:0] (Even-numbered PD select, M code output)									-
		*10		ABS_DATA[8:0] (Odd-numbered PD select, decode output)									-
		*11		ABS_DATA[8:0] (Odd-numbered PD select, M code output)									-
ABS adjust 1	R/W	***	001	*2	*1			R	ABS_COMPG[3:0]				100h
ABS adjust 2	R/W	***	010	ABS_COMPO[8:0]									000h
INC adjust	R/W	***	011	*1				GA[2:0]		GB[2:0]			000h
Monitor signal select 1	R/W	***	100	MON_SEL[3:0]				OUTSEL1[4:0]					000h
Monitor signal select 2	R/W	***	111	*1				OUTSEL2[4:0]					000h

SEL[2:0] entries with "*" are don't care values.
*1: Reserved. Set to 0 for normal operation.
*2: Version identification register with default value of 1 (Reserved). Set to 1 for write commands.

9.12.4. Absolute I/V converter resistance adjustment register (R)

The R register (address: 001b) sets the I/V converter resistance for the absolute signal. The I/V converter resistance can be set to 2.95MΩ or 5.90MΩ. Changing the value of the I/V converter resistance enables the amplitude of the absolute signal to be increased without changing the LED current.

R	I/V converter resistance
0	2.95MΩ
1	5.90MΩ

9.12.5. Absolute binarization voltage gain adjustment register (ABS_COMPG[3:0])

The ABS_COMPG[3:0] register (address: 001b) sets the gain relative to the light level when determining the threshold voltage for binarizing the absolute signal.

For an overview of the setting, see "9.5. Absolute Binarization Voltage Adjustment Function."

ABS_COMPG				Gain (typ.)
[3]	[2]	[1]	[0]	
1	0	0	0	0.096
1	0	0	1	0.138
1	0	1	0	0.180
1	0	1	1	0.222
1	1	0	0	0.264
1	1	0	1	0.306
1	1	1	0	0.347
1	1	1	1	0.389
0	0	0	0	0.431
0	0	0	1	0.473
0	0	1	0	0.515
0	0	1	1	0.557
0	1	0	0	0.599
0	1	0	1	0.640
0	1	1	0	0.682
0	1	1	1	0.721

V_{COMP} can be calculated by the following formula.

$$V_{COMP} = V_{COMP\_DAC} - G_{VCOMP} \times \left(\overline{INC\ PD} - V_{COMP\_DAC}\right)$$

G_{VCOMP} : Gain value (Set the ABS_COMPG[3:0] register)

V_{COMP_DAC} : Offset voltage (Set the ABS_COMPO[8:0] register)

$\overline{INC\ PD}$: Average value of the incremental signal(INC A+, INC A-, INC B+, INC B-)

9.12.6. Absolute binarization voltage offset adjustment register (ABS_COMPO[8:0])

The ABS_COMPO[8:0] register (address: 010b) sets the threshold voltage offset for binarizing the absolute signal.

For an overview of the setting, see "9.5. Absolute Binarization Voltage Adjustment Function."

ABS_COMPO									Offset voltage* (V_{DD}=3.0V)
[8]	[7]	[6]	[5]	[4]	[3]	[2]	[1]	[0]	
1	0	0	0	0	0	0	0	0	1.1265V
1	0	0	0	0	0	0	0	1	1.1279V
1	0	0	0	0	0	0	1	0	1.1294V
1	0	0	0	0	0	0	1	1	1.1309V
				.					.
				.					.
1	1	1	1	1	1	1	0	1	1.4971V
1	1	1	1	1	1	1	1	0	1.4984V
1	1	1	1	1	1	1	1	1	1.5000V
0	0	0	0	0	0	0	0	0	1.5015V
0	0	0	0	0	0	0	0	1	1.5029V
0	0	0	0	0	0	0	1	0	1.5044V
0	0	0	0	0	0	0	1	1	1.5059V
				.					.
				.					.
0	1	1	1	1	1	1	0	0	1.8706V
0	1	1	1	1	1	1	0	1	1.8721V
0	1	1	1	1	1	1	1	0	1.8735V
0	1	1	1	1	1	1	1	1	1.8750V

* The offset voltage adjustment value (V_{COMP_DAC}) depends on the V_{DD} voltage.

$$V_{COMP\_DAC} = \frac{V_{DD}}{2} + \frac{V_{DD}}{4} \cdot \frac{\text{ABS\_COMPO}[8:0]+1}{2^9}$$

(ABS_COMPO[8:0] is -256 to 255 in 2's complement representation)

9.12.7. Incremental Phase A/Phase B I/V conversion gain setting register (GAB[2:0])

The GAB[2:0] register (address: 011b) sets the I/V conversion gain of the incremental phase A signal and incremental phase B signal. The gain of the phase A signal and phase B signal can be adjusted independently.

For an overview of the setting, see "9.6. Incremental Output, I/V Conversion Gain Adjustment Function."

GA[2:0] GB[2:0]			I/V conversion gain [dB]	(Magnification notation)
[2]	[1]	[0]		
0	0	0	±0dB	1.00×
0	0	1	+3dB	1.41×
0	1	0	+6dB	2.00×
0	1	1	+9dB	2.82×
1	0	0	+12dB	3.98×
1	0	1	+15dB	5.62×
1	1	0	+18dB	7.94×
1	1	1	+21dB	11.22×

9.12.8. Monitor target signal setting register (MON_SEL[3:0])

The MON_SEL[3:0] register (address: 100b) specifies the internal signals to output on the monitor pins.

For details about each internal signal, see "9.7. Internal Signal Monitor Function."

MON_SEL				MON1 pin	MON2 pin
[3]	[2]	[1]	[0]		
0	0	0	0	Hi-Z	Hi-Z
0	0	0	1	MA	MB
0	0	1	0	ABS PD *1	ABS PD *1
0	0	1	1	ABS PD *1	ABS Co *1
0	1	0	0	ABS Co *1	ABS Co *1
0	1	0	1	V_{COMP}	$V_{COMP\ DAC}$
0	1	1	0	V_{COMP}	ABS PD *1
0	1	1	1	V_{COMP}	ABS Co *1
1	0	0	0	INC A+	INC A-
1	0	0	1	INC B+	INC B-
1	0	1	0	INC A+	INC B+
1	0	1	1	INC A-	INC B-
1	1	0	0	V_{COMP}	INC A+
1	1	0	1	V_{COMP}	INC B+
1	1	1	0	V_{COMP}	INC A-
1	1	1	1	V_{COMP}	INC B-

*1: The output of internal signals can be configured using the OUTSEL1[4:0] and OUTSEL2[4:0] settings.

9.12.9. Monitor target signal setting register 2 (OUT_SEL1[4:0], OUT_SEL2[4:0])

The OUTSEL1[4:0] register (address: 100b) and OUTSEL2[4:0] register (address: 111b) specify the numbers of the internal signals to output on the monitor pins when ABS PD and ABS Co settings are configured (MON_SEL[3:0]=2h, 3h, 5h, 6h). OUTSEL1[4:0] specifies the internal signal to output on the MON1 pin, and OUTSEL2[4:0] specifies the internal signal to output on the MON2 pin.

When the MON_SEL[3:0] register is set to a value that does not select an ABS PD or ABS Co (MON_SEL[3:0]=0h, 1h, 4h, 7h, 8h, 9h, Ah, Bh, Ch, Dh, Eh, Fh), the OUTSEL1[4:0] and OUTSEL2[4:0] settings are ignored.

For details about each internal signal, see "9.7. Internal Signal Monitor Function."

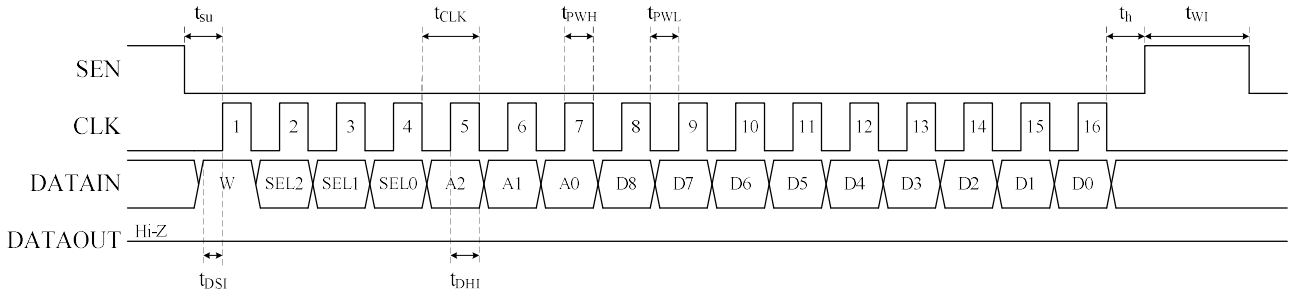
OUTSEL1, OUTSEL2					Selected	Selected
[4]	[3]	[2]	[1]	[0]	ABS PD	ABS Co
0	0	0	0	0	ABS PD0	ABS Co0
0	0	0	0	1	ABS PD1	ABS Co1
0	0	0	1	0	ABS PD2	ABS Co2
0	0	0	1	1	ABS PD3	ABS Co3
0	0	1	0	0	ABS PD4	ABS Co4
0	0	1	0	1	ABS PD5	ABS Co5
0	0	1	1	0	ABS PD6	ABS Co6
0	0	1	1	1	ABS PD7	ABS Co7
0	1	0	0	0	ABS PD8	ABS Co8
0	1	0	0	1	ABS PD9	ABS Co9
0	1	0	1	0	ABS PD10	ABS Co10
0	1	0	1	1	ABS PD11	ABS Co11
0	1	1	0	0	ABS PD12	ABS Co12
0	1	1	0	1	ABS PD13	ABS Co13
0	1	1	1	0	ABS PD14	ABS Co14
0	1	1	1	1	ABS PD15	ABS Co15
1	0	0	0	0	ABS PD16	ABS Co16
1	0	0	0	1	ABS PD17	ABS Co17
1	0	0	1	0	ABS PD18	ABS Co18
1	0	0	1	1	ABS PD19	ABS Co19
1	0	1	0	0	Hi-Z	Hi-Z
1	0	1	0	1	Hi-Z	Hi-Z
1	0	1	1	0	Hi-Z	Hi-Z
1	0	1	1	1	Hi-Z	Hi-Z
1	1	0	0	0	Hi-Z	Hi-Z
1	1	0	0	1	Hi-Z	Hi-Z
1	1	0	1	0	Hi-Z	Hi-Z
1	1	0	1	1	Hi-Z	Hi-Z
1	1	1	0	0	Hi-Z	Hi-Z
1	1	1	0	1	Hi-Z	Hi-Z
1	1	1	1	0	Hi-Z	Hi-Z
1	1	1	1	1	Hi-Z	Hi-Z

10. TIMING DIAGRAMS

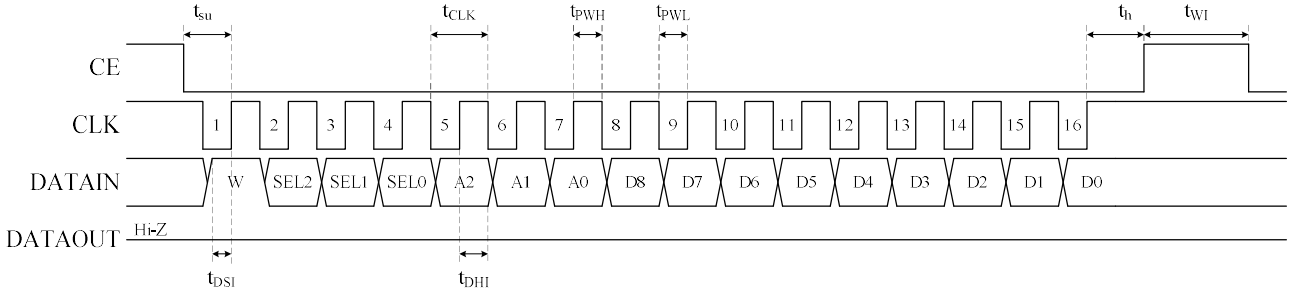
10.1. Serial Interface

[Write timing]

SPI MODE0

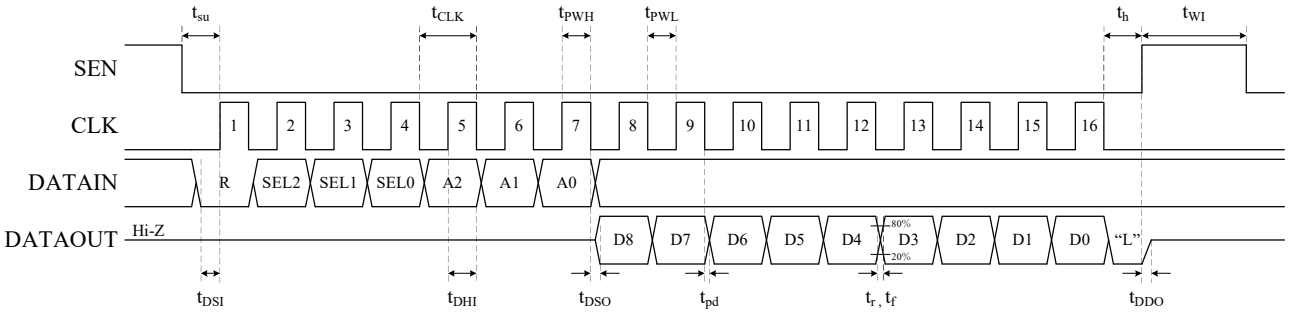


SPI MODE3

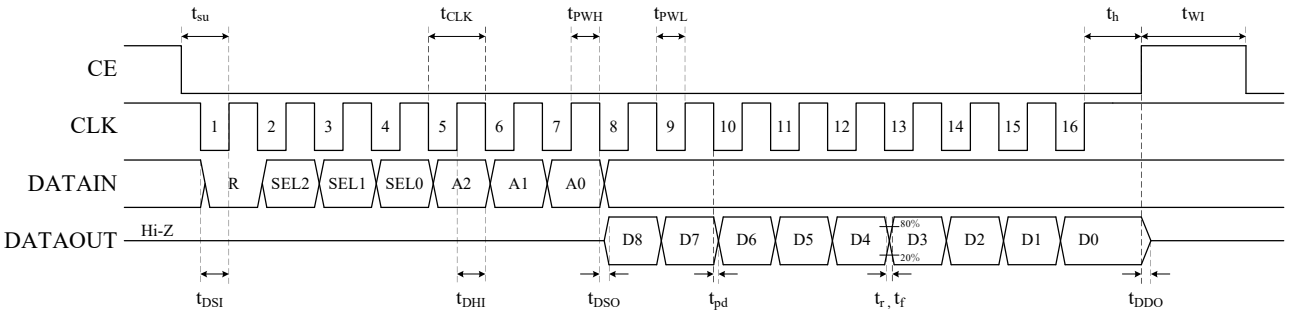


[Read timing]

SPI MODE0



SPI MODE3



V_{DD}=3.0V, V_{SS}=0V, T_a=25°C, C_L=15pF unless otherwise noted

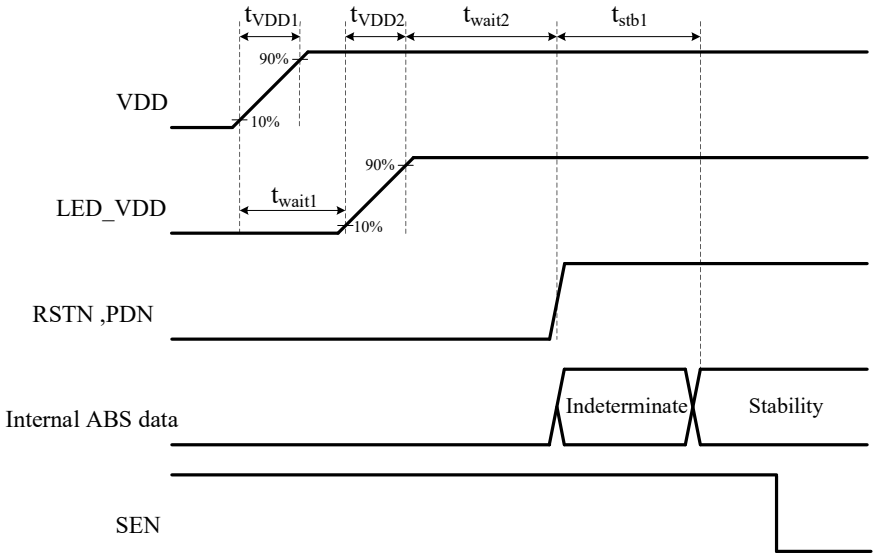
Parameter	Symbol	Conditions	MIN	TYP	MAX	Unit
High-level pulse width	t_{PWH}		90	-	-	ns
Low-level pulse width	t_{PWL}		90	-	-	ns
Pulse cycle time	t_{CLK}		200	-	-	ns
Setup time	t_{su}		30	-	-	ns
Hold time	t_h		60	-	-	ns
Interface wait time	t_{WI}		300	-	-	ns
Input data setup time	t_{DSI}		20	-	-	ns
Input data hold time	t_{DHI}		90	-	-	ns
Output data setup time	t_{DSO}		-	-	50	ns
Output data disable time	t_{DDO}		-	-	50	ns
Propagation delay time	t_{pd}		-	-	50	ns
Output rise time	t_r		-	-	8	ns
Output fall time	t_f		-	-	8	ns

10.2. Power-Up Procedure

Do not apply the LED_VDD voltage before the VDD voltage (t_{wait1}>0).

There are no specified power-on rise time ratings (t_{VDD1}, t_{VDD2}). However, before the power is turned on, set the RSTN and PDN pins to the same potential as VSS (standby state).

The startup stabilization time referred to here is the time required to recover from the absolute circuit power-down state (from standby mode). The ABS output data is stable after 1ms has elapsed since releasing the absolute circuit power-down state (from standby mode).

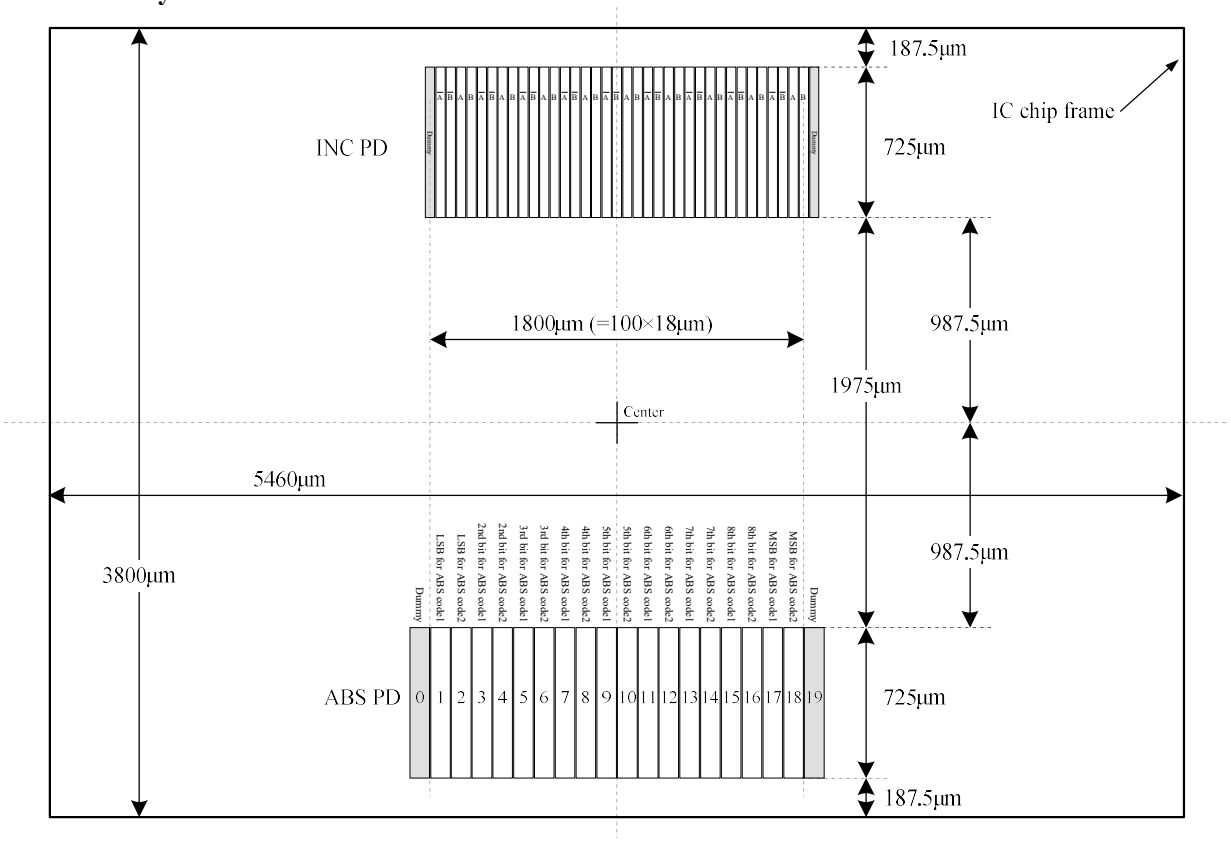


V_{DD}=V_{LVDD}=3.0V, V_{SS}=0V, T_a=25°C unless otherwise noted

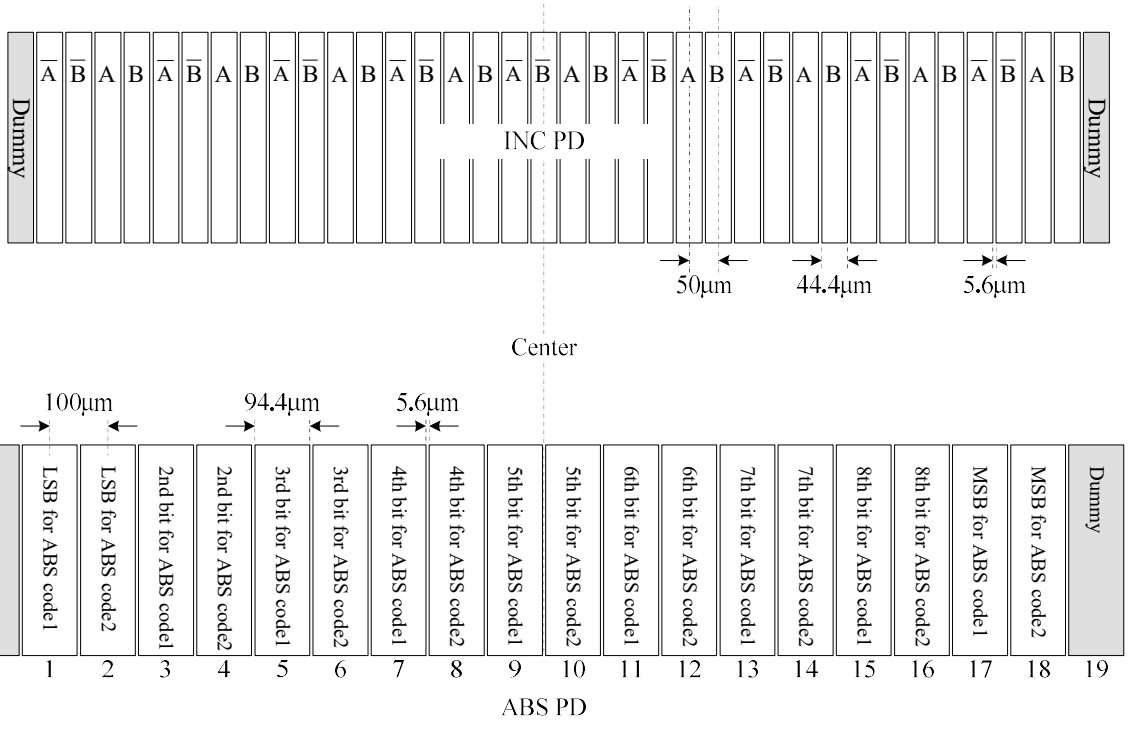
Parameter	Symbol	Conditions	MIN	TYP	MAX	Unit
Standby release wait time	t_{wait2}		1	-	-	ms
Startup stabilization time	t_{stbl}		-	-	1	ms

11. PD LAYOUT and DIMENSIONS

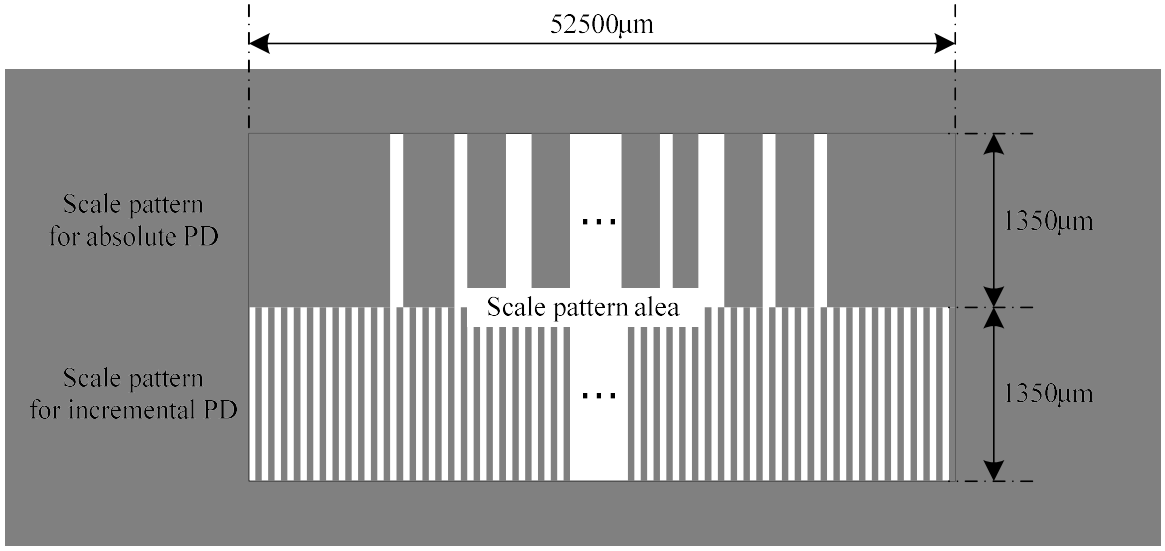
11.1. PD Layout



11.2. PD Width Dimensions



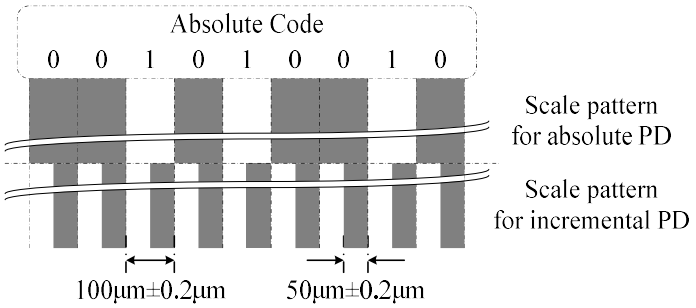
12. RECOMMENDED SCALE PATTERN



Non-reflection area
(Reflectance ≒ 6%)

Reflection area
(Reflectance ≧ 60%)

	Value
ABS pattern width	100µm
INC pattern width	50µm / 50µm
INC pattern pitch	100µm



12.1. ABS Pattern Table (0: Non-reflective, 1: Reflective)

M-code to binary code conversion using the built-in ROM is supported using the following ABS pattern. If you use a pattern other than the recommended ABS pattern, do not read the ABS code (binary).

No	Pattern	No	Pattern	No	Pattern	No	Pattern	No	Pattern
1	0	15	1	29	1	43	1	57	0
2	0	16	0	30	0	44	1	58	0
3	0	17	0	31	1	45	1	59	0
4	0	18	0	32	0	46	0	60	1
5	0	19	1	33	1	47	0	61	1
6	0	20	1	34	0	48	0	62	0
7	0	21	0	35	1	49	1	63	1
8	0	22	0	36	1	50	0	64	1
9	0	23	1	37	0	51	0	65	0
10	0	24	0	38	1	52	1	66	0
11	1	25	0	39	1	53	0	67	1
12	0	26	0	40	0	54	1	68	1
13	0	27	1	41	0	55	0	69	1
14	0	28	1	42	0	56	1	70	1

No	Pattern	No	Pattern	No	Pattern	No	Pattern	No	Pattern
71	1	131	0	175	0	219	1	263	0
72	0	132	1	176	0	220	1	264	1
73	0	133	1	177	0	221	0	265	0
74	1	134	1	178	0	222	0	266	1
75	1	135	1	179	1	223	1	267	0
76	1	136	1	180	1	224	1	268	1
77	1	137	1	181	1	225	1	269	0
78	0	138	1	182	0	226	0	270	1
79	0	139	1	183	0	227	0	271	1
80	0	140	1	184	1	228	0	272	1
97	0	141	0	185	1	229	0	273	1
98	0	142	0	186	0	230	0	274	1
99	0	143	0	187	0	231	0	275	0
100	0	144	0	188	0	232	1	276	1
101	0	145	1	189	0	233	1	277	0
102	1	146	1	190	1	234	1	278	1
103	0	147	1	191	0	235	0	279	1
104	0	148	1	192	0	236	1	280	0
105	1	149	0	193	1	237	1	281	1
106	1	150	1	194	0	238	1	282	0
107	0	151	1	195	0	239	0	283	0
108	0	152	1	196	0	240	1	284	0
109	1	153	0	197	1	241	0	285	0
110	1	154	0	198	0	242	0	286	0
111	1	155	0	199	1	243	1	287	1
112	0	156	0	200	0	244	1	288	1
113	1	157	1	201	1	245	1	289	0
114	0	158	0	202	1	246	1	290	1
115	0	159	1	203	1	247	0	291	1
116	0	160	1	204	0	248	1	292	1
117	1	161	0	205	1	249	0	293	0
118	1	162	0	206	0	250	1	294	1
119	1	163	1	207	1	251	0	295	1
120	1	164	1	208	1	252	0	296	0
121	1	165	0	209	1	253	1	297	1
122	0	166	1	210	1	254	0	298	1
123	1	167	1	211	0	255	1	299	0
124	1	168	0	212	0	256	0	300	1
125	1	169	1	213	1	257	0	301	0
126	1	170	1	214	0	258	0	302	1
127	0	171	1	215	0	259	0	303	1
128	0	172	1	216	1	260	0	304	0
129	0	173	0	217	0	261	0	305	0
130	0	174	1	218	1	262	1	306	0

No	Pattern
307	0
308	0
309	1
310	0
311	1
312	1
313	1
314	0
315	1
316	1
317	1
318	1
319	1
320	0
321	0
322	0
323	1
324	1
325	1
326	1
327	0
328	0
329	1
330	1
331	0
332	1
333	0
334	0
335	1
336	1
337	0
338	1
339	0
340	1
341	1
342	1
343	0
344	0
345	0
346	1
347	1
348	0
349	1
350	0

No	Pattern
351	0
352	0
353	1
354	0
355	1
356	1
357	1
358	1
359	1
360	1
361	1
362	0
363	1
364	0
365	0
366	1
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368	1
369	1
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377	0
378	1
379	1
380	0
381	0
382	0
383	1
384	1
385	0
386	0
387	0
388	0
389	0
390	0
391	0
392	1
393	1
394	0

No	Pattern
395	0
396	1
397	1
398	0
399	0
400	1
401	0
402	1
403	0
404	1
405	1
406	0
407	0
408	1
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410	0
411	1
412	1
413	1
414	1
415	1
416	1
417	0
418	1
419	1
420	0
421	1
422	0
423	0
424	1
425	0
426	0
427	1
428	0
429	0
430	1
431	1
432	0
433	1
434	1
435	1
436	1
437	1
438	1

No	Pattern
439	0
440	0
441	1
442	0
443	1
444	1
445	0
446	1
447	0
448	1
449	0
450	0
451	0
452	0
453	1
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457	0
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467	1
468	0
469	0
470	1
471	0
472	1
473	1
474	1
475	1
476	0
477	1
478	1
479	0
480	0
481	0
482	0

No	Pattern
483	1
484	1
485	0
486	1
487	0
488	1
489	0
490	1
491	0
492	0
493	1
494	1
495	1
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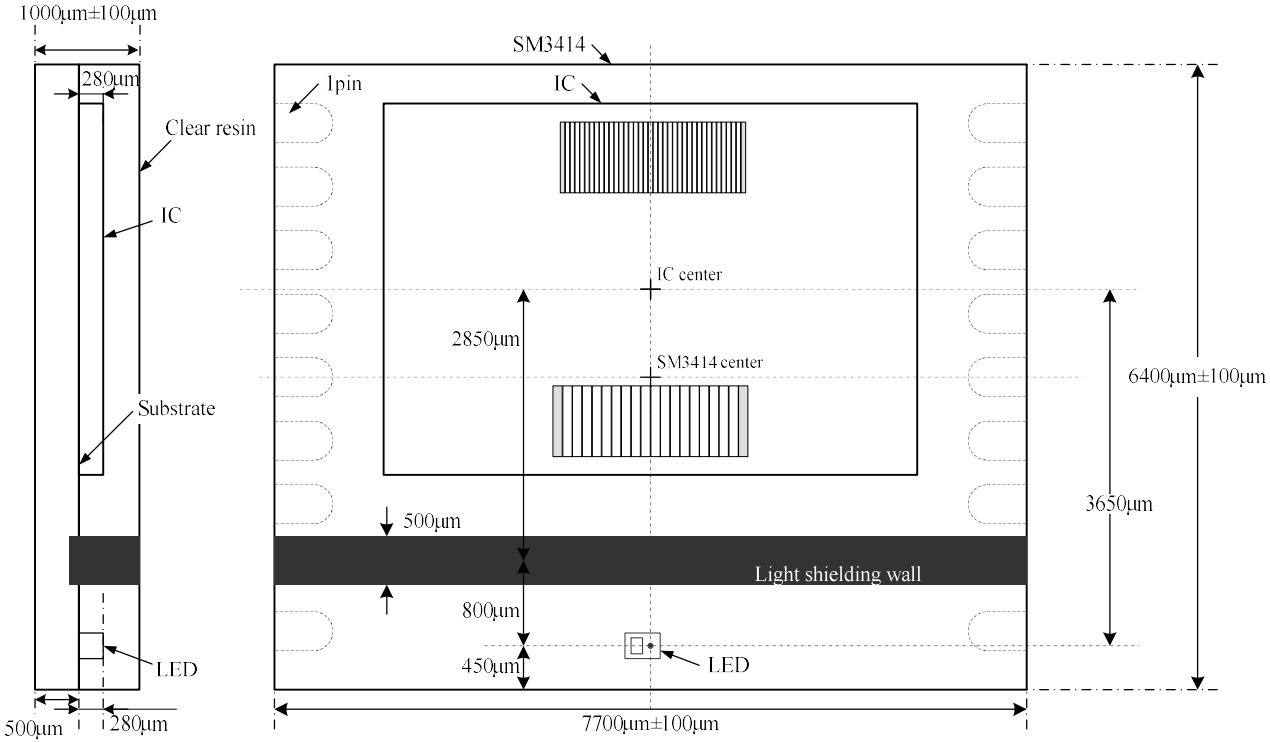
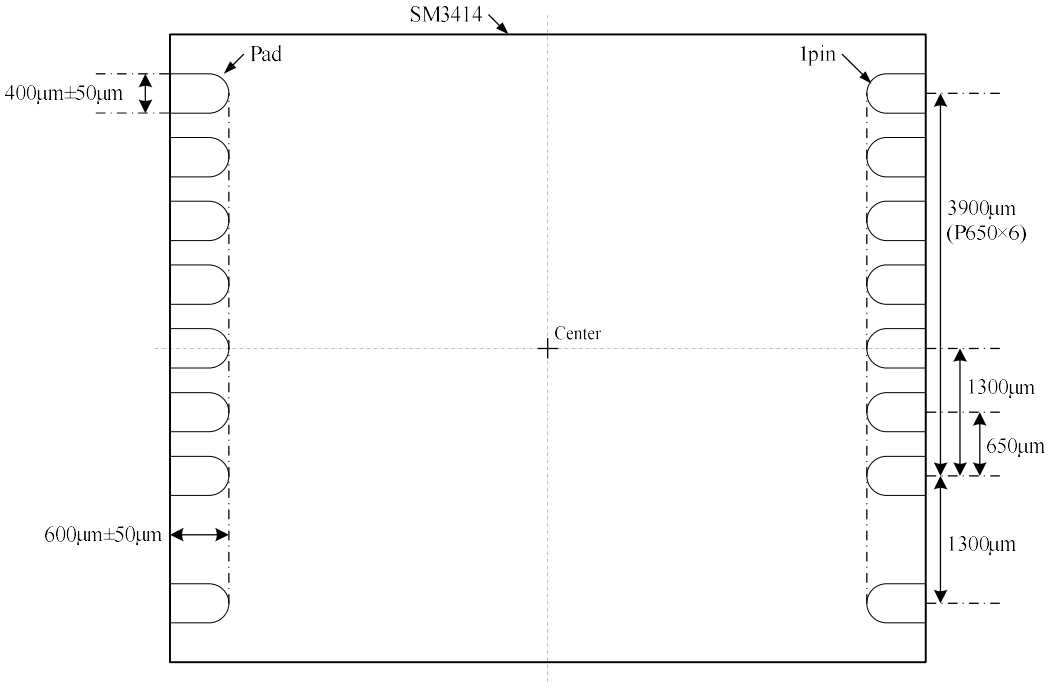
500	0
501	0
502	0
503	1
504	1
505	0
506	0
507	0
508	1
509	0
510	0
511	0
512	0
513	1
514	0
515	0
516	0
517	0
518	0
519	0
520	0
521	0
522	0
523	0
524	0
525	0

13. EXTERNAL DIMENSIONS

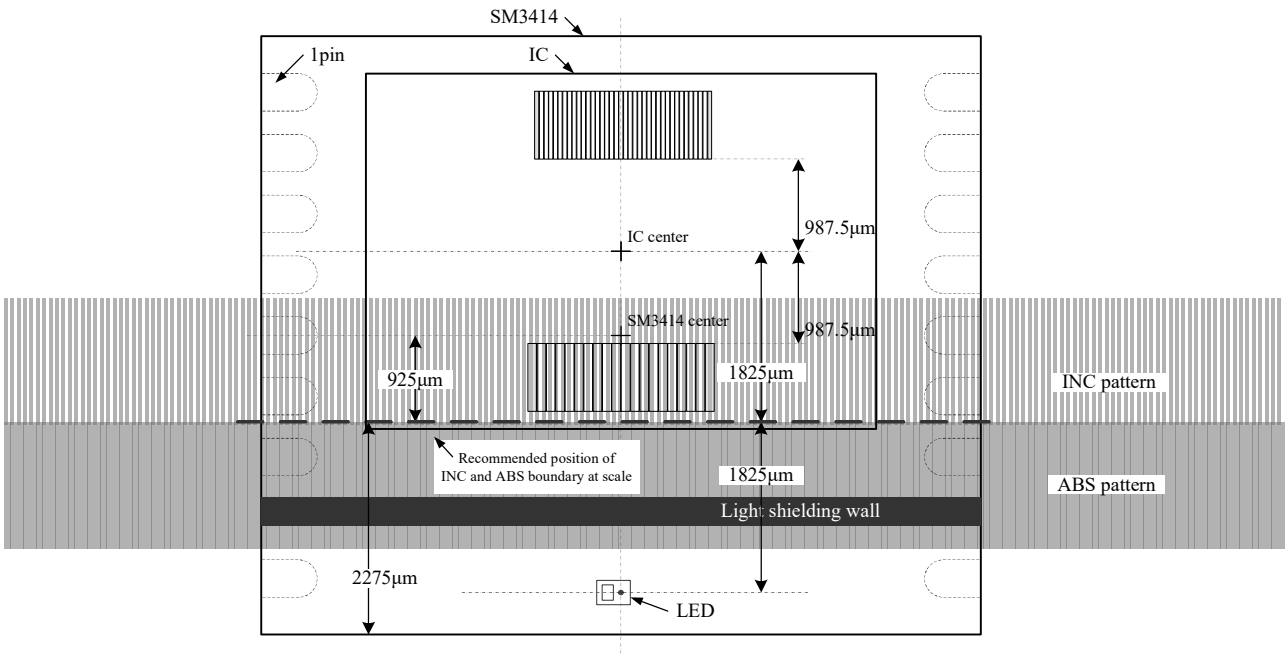


Top view

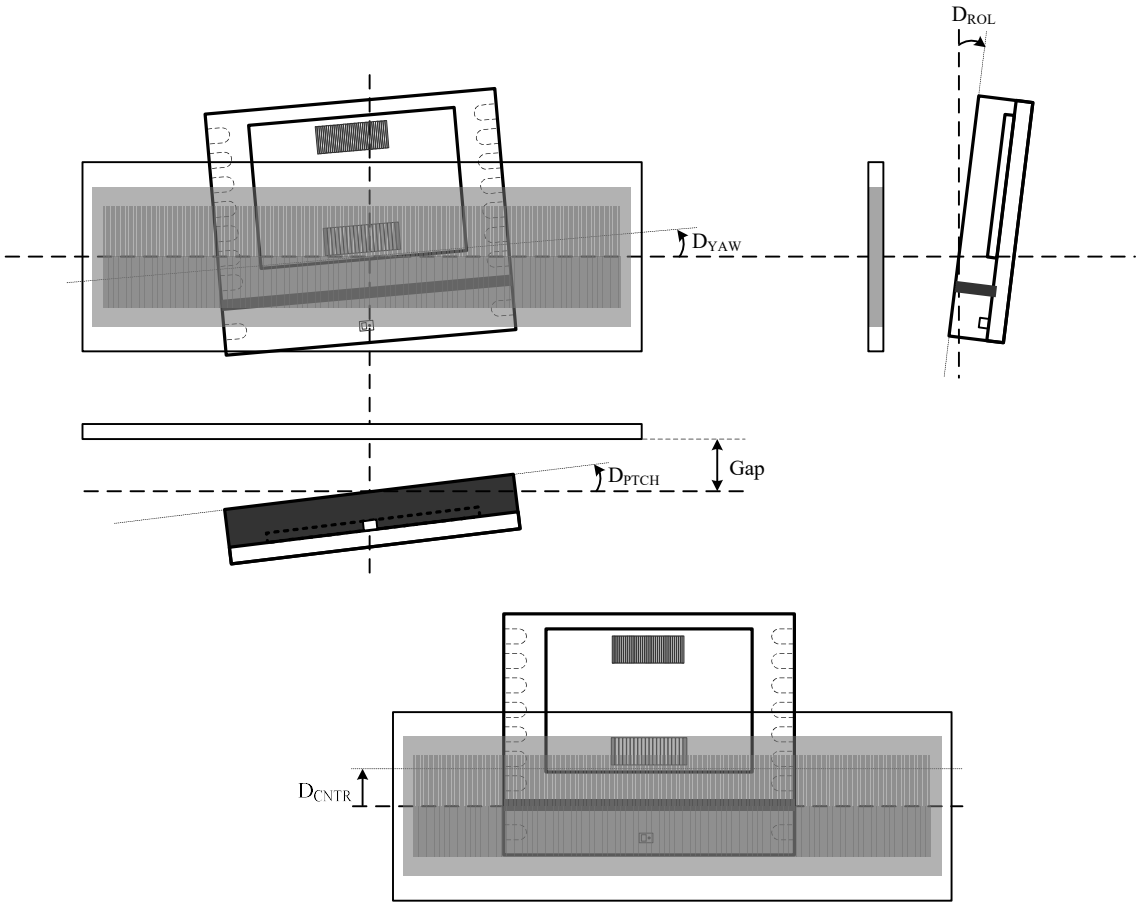


Bottom view

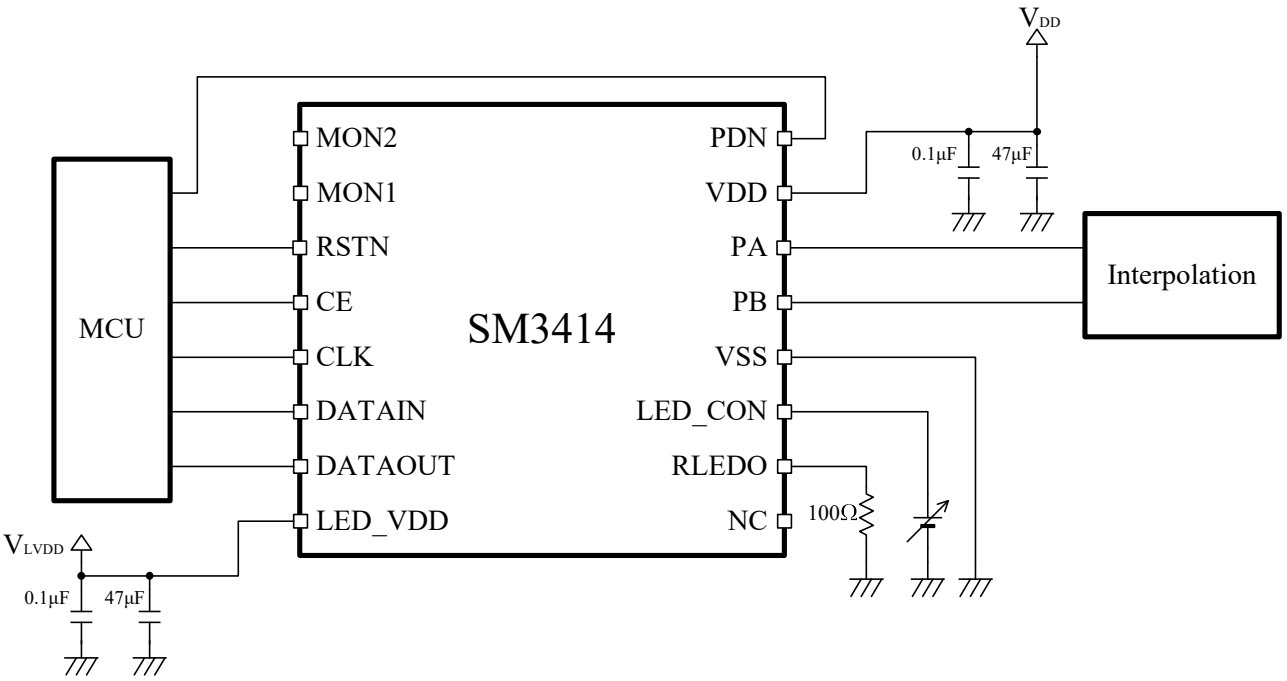
14. RECOMMENDED SCALE MOUNTING POSITION



14.1. Mounting Tolerance Definition



15. TYPICAL APPLICATION CIRCUIT



16. USAGE AND PRECAUTIONS

This product is designed and manufactured to the generally accepted standards of reliability as expected for use in general electronic and electrical equipment, such as personal equipment, machine tools, and measurement equipment. This product is not designed and manufactured to be used in any other special equipment requiring extremely high level of reliability and safety, such as aerospace equipment, nuclear power control equipment, medical equipment, transportation equipment, disaster prevention equipment, security equipment.

If you wish to use this product in equipment requiring extremely high level of reliability, please contact our sales department or representative in advance.

In the event that this product is used in such equipment, please take scrupulous care and apply fail-safe techniques including redundancy and malfunction prevention in order to prevent damage to life, health, property, or infrastructure etc. in case there is some malfunction in the product.

Please pay your attention to the following points at time of using the products shown in this document.

1. The products shown in this document (hereinafter "Products") are designed and manufactured to the generally accepted standards of reliability as expected for use in general electronic and electrical equipment, such as personal equipment, machine tools and measurement equipment. The Products are not designed and manufactured to be used in any other special equipment requiring extremely high level of reliability and safety, such as aerospace equipment, nuclear power control equipment, medical equipment, transportation equipment, disaster prevention equipment, security equipment. The Products are not designed and manufactured to be used for the apparatus that exerts harmful influence on the human lives due to the defects, failure or malfunction of the Products.
   If you wish to use the Products in that apparatus, please contact our sales section in advance.
   In the event that the Products are used in such apparatus without our prior approval, we assume no responsibility whatsoever for any damages resulting from the use of that apparatus.
2. NPC reserves the right to change the specifications of the Products in order to improve the characteristics or reliability thereof.
3. The information described in this document is presented only as a guide for using the Products. No responsibility is assumed by us for any infringements of patents or other rights of the third parties which may result from its use. No license is granted by implication or otherwise under any patents or other rights of the third parties. Then, we assume no responsibility whatsoever for any damages resulting from that infringements.
4. The constant of each circuit shown in this document is described as an example, and it is not guaranteed about its value of the mass production products.
5. In the case of that the Products in this document falls under the foreign exchange and foreign trade control law or other applicable laws and regulations, approval of the export to be based on those laws and regulations are necessary. Customers are requested appropriately take steps to obtain required permissions or approvals from appropriate government agencies.

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