Problem#1

Test case#1

$T_1 = a=4, b=7, c=6, d=1$

pa = 4
pb = 1

line(6)
pa→get() = Object of A
pb→get() = object of B

4 > 1
pa = 1
pb = 4

line(13)
pc = 6

line(14)
pa→get() = object of B
pc→get() = object of C

1 > 6 (false)

line(18)
pa→get() = Object of B
pc→get() = object of C
pb→get() = Object of A

1+6 >= 4 (True)

Test case#2

$T_2 = a=3, b=3, c=1, d=-1$

pa = 3
pb = 1

line(6)
pa→get() = Object of A
pb→get() = object of B

3 > 1
pa = 1
pb = 3

line(13)
pc = 0

line(14)
1 > 0
pa = 0 , pa→get() = Object of B
pc = 1 , pc→get() = object of D

line(18)
pb→get() = Object of A
0+1 >= 3 = false

Test case#3

$T_3 = a=3, b=3, c=4, d=-1$

pa = 3
pb = 4

line(6)
pa→get() = Object of A
pb→get() = Object of B

3 > 4 = False

line 13
pc = 4

line(14)
pa→get() = Object of A
pb→get() = Object of B
3>4 - false

line(18)
pa→get() = Object of A
pc→get() = Object of D
pb→get() = Object of B
3+4 >= 4 (True)

Test case #4

T4 = a=7, b=4, c=6, d=-1

pa = 7
pb = -1

line(6)
pa→get() = Object of A
pb→get() = Object of B
7>1 (true)
pa = -1
pb = 7

line(13)
pc = 14

line 14
pa→get() = Object of B
pc→get() = Object of D
-1 > 4 = false

line 18
pa→get() = Object of B
pc→get() = Object of D
pb→get() = Object of A
-1 + 4 >= 7 (false)

Test case #5

T5 = a=9, b=5, c=6, d=10

pa = 9
pb = 10

line(6)
pa→get() = Object of A
pb→get() = Object of B
9>10 (false)

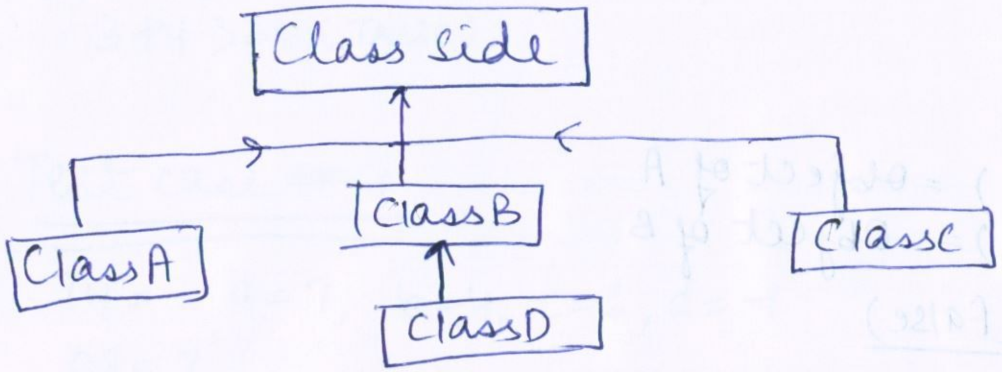
line(13)
pc = 6

line (14) → line(14)
pa→get() = Object of A
pc→get() = Object of C
9>6 (True)
pa = 6
pc = 9

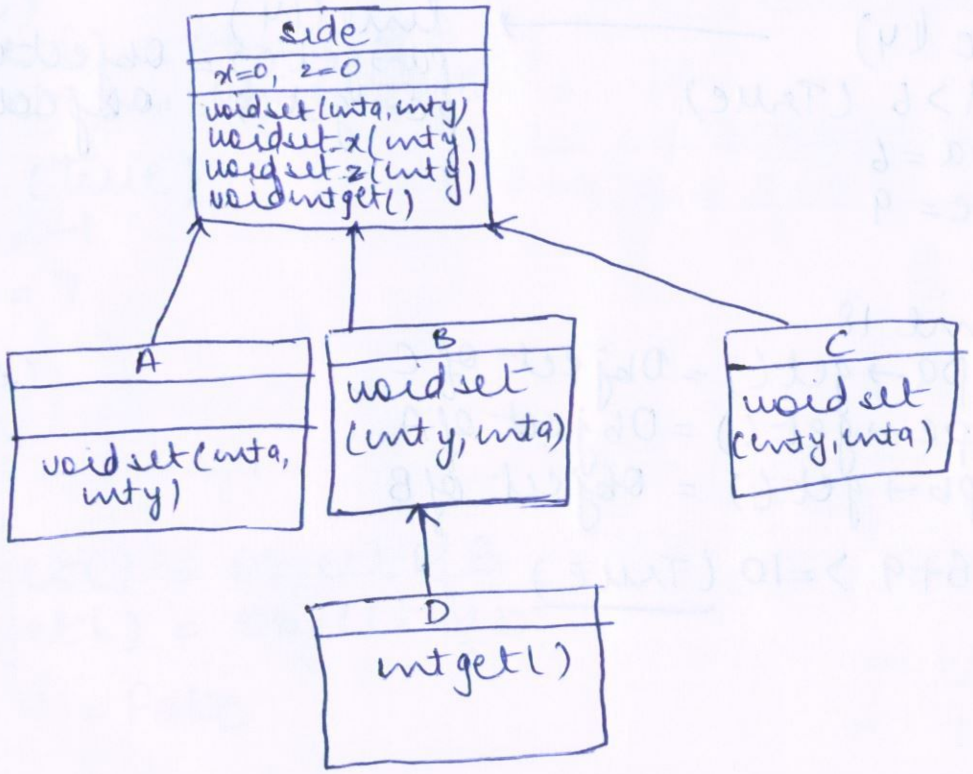
line 18
pa→get() = Object of C
pc→get() = Object of A
pb→get() = Object of B
6+9 >= 10 (True)

Test cases:-

Test case#1 = a=4, b=7, c=6, d=1
Test case#2 = a=3, b=3 c=1, d=-1
Test case#3 = a=3, b=3, c=4, d=-1
Test case#4 = a=7, b=4, c=6, d=-1
Test case#5 = a=9, b=5, c=6, d=10



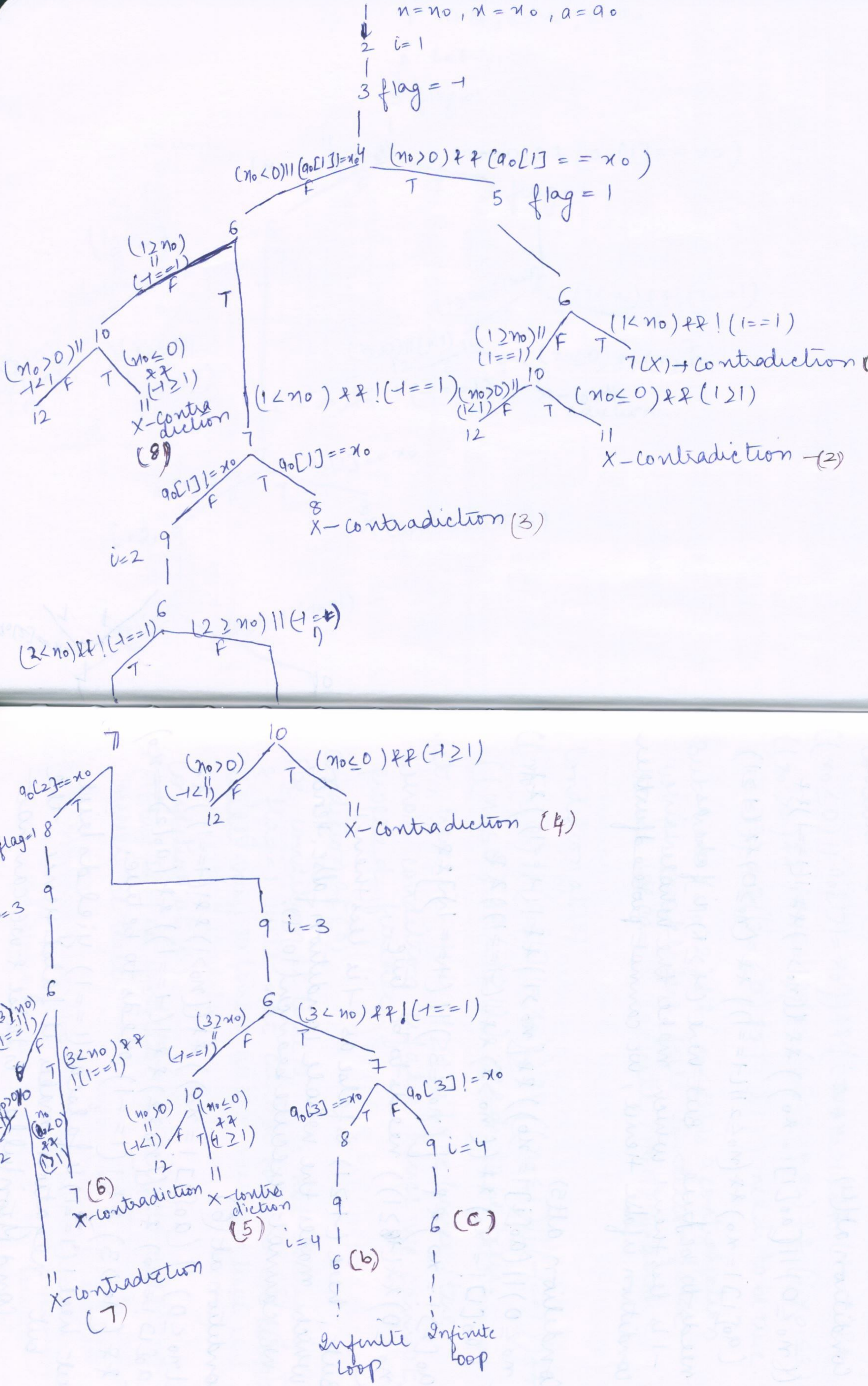
Polymorphic calls at line number = 6, 14, 18



Problem#2

```
1.   int search(int n, int x, int a[])
     { int i, flag, z;
2.   i=1;
3.   flag=-1;
4,5  if (n>0)&&(a[i]==x)) flag=1;
6    while((i<n)&& !(flag==1)){
7,8        if (a[i]==x) flag=1;
9          i++;
     };
10,11  if (n<=0)&&(flag>=1)) return 1;
12       else return 0;
     };
```

Symbolic Tree



Problem#2 (Explaination)

Condition at(4)

$((n_0 \le 0) \,||\, [a_0[1] != x_0)) \,\&\&\, ((n_0 > 1) \,\&\&\, !(-1==1) \,\&\&$

$(a_0[1] != x_0) \,\&\&\, (n_0 \le 2 \,||\, (-1==1)) \,\&\&\, (n_0 \ge 0) \,\&\&\, (-1 \ge 1)$

needs to be true. But here $(-1 \ge 1)$ is false as -1 is less then 1 which makes the whole condition is false. Hence, we cannot proceed further

Condition at(5)

$(n_0 \le 0) \,||\, (a_0[i] != x_0)) \,\&\&\, [n_0 > 1) \,\&\&\, !(-1==1)) \,\&\&$
$(a_0[1] != x_0) \,\&\&\, ((n_0 > 2) \,\&\&\, !(-1==1)) \,\&\&$
$a_0[2] != x_0) \,\&\&\, [(n_0 \le 3) \,||\, (1==1)] \,\&\&$
$(n_0 \le 0) \,\&\&\, (-1 \ge 1))$ needs to be true.

But, here $(-1 \ge 1)$ is false as -1 is less then 1 which makes the whole condition false. Hence, we cannot execute branch(10,11).

Condition at (6)

$(l n_0 \le 0) \,||\, (a_0[1] != x_0)) \,\&\&\, ((n_0 > 1) \,\&\&\, !(-1==1)) \,\&\&$
$(a_0[1] != x_0) \,\&\&\, ((n_0 > 2) \,\&\&\, !(-1==1)) \,\&\&\, (a_0(2) == x_0)$
$\&\&\, (n_0 > 3) \,\&\&\, !(1==1)$ needs to be true.

But here $!(1==1)$ is false as $(1==1)$ yields true but negation makes it false. Hence, the condition fully is false & we cannot proceed further.

Condition at (7)

$((n_0 \le 0) \,||\, a_0[1] != x_0)) \,\&\&\, ((n_0 > 1) \,\&\&\, !(-1==1)) \,\&\&$
$((n_0 > 2) \,\&\&\, !(-1==1)) \,\&\&\, (a_0[2] == x_0) \,\&\&\, ((x_0 \le 3) \,||$
$(1==1)) \,\&\&\, ((n_0 \le 0) \,\&\&\, (1 \ge 1))$ needs to be true.

But here $(n_0 > 2) \,\&\&\, (n_0 \le 0)$ is a contradiction which makes the full condition false hence we can't execute (10,11) branch.

Condition at(8)

$((n_0 \le 0) \,||\, (a_0[1] != x_0)) \,\&\&\, ((n_0 \le 1) \,||\, (-1==1)) \,\&\&$
$((n_0 \le 0) \,\&\&\, (-1 \ge 1))$ needs to be true.

But, here in this $-1 \ge 1$ is false hence, the whole condition is false hence we cannot proceed further.

Condition at (b)

For condition at line 10, n is not changing & flag=1 will not change forever. In loop n will vary so line 10 will never be true

Condition at (c)

Flag is -1 so condition at line 10 will never be true.

condition at (1)

$((n_0 > 0) \&\& (a_0[1] == x_0) \&\& (n_0 > 1) \&\& !(1 == 1))$

since $1 == 1$ is true, $!(1 == 1)$ is false which makes the whole condition is false hence we cannot proceed further from line 7

condition at (2)

$((n_0 > 0) \&\& (a_0[1] == x_0)) \&\& ((1 \geq n_0) || (1 == 1) \&\& ((n_0 \leq 0) \&\& (1 \geq 1))$. If $n_0 > 0$ then $n_0 \leq 0$ cannot hold true, creating a contradiction at line 11, therefore, $n_0 > 0 \&\& n_0 \leq 0$ is a contradiction and branch (10, 11) is non executable

condition at (3)

$((n_0 \leq 0) || (a_0[1] != x_0)) \&\& ((n_0 > 1) \&\& !(1 == 1)) \&\& (a_0[i] == x_0)$

$\Rightarrow (n_0 \leq 0) \&\& (n_0 > 1) \&\& !(1 == 1) \&\& a_0[1] == x_0$ has to be true or $a_0[1] != x_0) \&\& (n_0 > 1) \&\& !(1 == 1) \&\& (a_0[1] == x_0)$ has to be true.

$\Rightarrow$ $n_0 \leq 0 \&\& n_0 > 1$ is contradicting meaning we consider $(a_0[1] != x_0) \&\& (n_0 > 1) \&\& (1 == 1) \&\& (a_0[1] == x_0)$. Hence, $(a_0[1] != x_0) \&\& (a_0[1] == x_0)$ is contradicting hence we cannot proceed further

Problem #3

Loop Invariant

Predicate 6

$\boxed{\text{for all } (i+1 \leq t \leq n) : min \leq |a[t]|}$

K = no of time execution is at predicate 6

1) $K = 1$

loop entry path

Path = 1, 2, 3, 4, 6

$i = n-1$, $min = a[n]$

for all $(i+1 \leq t \leq n)$: $min \leq |a[t]|$

for all $(n \geq t \geq n)$: $min \leq |a[t]|$

for all $(n \geq t > n+1)$: $min \leq |a[t]|$

$|a[n]| \geq a[n]$ is substituting for $min = (a[n] \& t = n)$

path = 1, 2, 3, 4, 5, 6

$min = -a[n]$, $i = n-1$

for all $(i+1 \leq t \leq n)$: $min \leq |a[t]|$

for all $(n-1+1 \leq t \leq n)$: $min \leq |a[t]|$

for all $(n \geq t \geq n)$: $min \leq |a[t]|$

$\Rightarrow -a[n] \leq |a[n]| \Rightarrow$ true is substituted in place of $min = -a[n] \& t = n$

2) Assume for some value (K) loop invariant holds true

$$\boxed{\text{forall } (i_k+1 \le t \le n) : min_k \le |a[t]|}$$

~~conditions~~

3) Proving for k+1

Path = 6, 7, 8, 11, 6

6 = i_k
min_k

7 = $[([a i_k] \ge 0] \&\& (min_k > (a[i_k]))] \Rightarrow$ true

8 = $min_{k+1} = a[i_k]$

11 = $i_{k+1} = i_{k-1}$

6 = $i_{k+1} = i_{k-1}$

$min_{k+1} = a[i_k]$

forall $[i_{k+1} + 1 \le t \le n]$: $min_{k+1} \le |a[t]|$

forall $[i_k^{-1} + 1 \le t \le n]$: $min_{k+1} \le |a[t]|$

forall $[i_{k+1} \le t \le n]$: $min_{k+1} \le |a[t]| \&\& min_{k+1} \le |a[i_k]|$

$a[i_k] \ge 0 \&\& min_{k+1} = a[i_k]$

$\Rightarrow \therefore |a[i_k]| \le |a[i_k]| \Rightarrow$ true

forall $(i_k+1 \le t \le n)$: $min_{k+1} \le a[t]$

(i) $min_{k+1} < min_k \Rightarrow$ true

(ii) forall $(i_k+1 \le t \le n)$: $min_k \le |a[t]|$
forall $(i_k+1 \le t \le n)$: $min_{k+1} \le |a[t]|$

Path = 6, 7, 9, 10, 11, 6

6 = i_k
min_k

7 = $![a[i_k] \ge 0] \&\& (min_k > a[i_k])$

9 = $[a[i_k] < 0] \&\& (min_k > -a[i_k])$

10 = $min_{k+1} = -a[i_k]$

11 = $i_{k+1} = i_k^{-1}$

6 = $i_{k+1} = i_{k-1}$
$min_{k+1} = -a[i_k]$

$\Rightarrow [(a[i_k] < 0] \,||\, (min_k \le a[i_k]) \&\& [a(i_k) < 0] \&\& (min_k > -a[i_k]))$

$\Rightarrow ([a[i_k] < 0] \&\& [min_k > -a[i_k]]) \,||$
$([min_k \le a[i_k]] \&\& [a[i_k] < 0] \&\& [min_k > -a[i_k]])$

$\Rightarrow min_k > |a[i_k]|$

$\Rightarrow min_k > min_{k+1}$

forall ($i_{k+1} \le t \le n$) : $min_{k+1} \le |a[t]|$

forall ($i_{k-1}+1 \le t \le n$) : $min_{k+1} \le |a[t]|$

forall ($i_{k+1-1} \le t \le n$) : $min_{k+1} \le |a[t]|$

forall ($i_{k+1} \le t \le n$) : $min_{k+1} \le |a[t]|$ &&

~~$min_{k+1} \le |a[i_k]| < min_k$~~

$min_{k+1} \le |a[i_k]| < min_k$

$-a[i_k] \le |a[i_k]| \Rightarrow$ true

forall ($i_{k+1} \le t \le n$) : $min_{k+1} \le |a[t]|$

(i) $min_{k+1} < min_k \Rightarrow$ true

(ii) forall ($i_k+1 \le t \le n$) : $min_k \le |a[t]|$

forall ($i_k+1 \le t \le n$) : $min_{k+1} \le |a[t]|$

Path = 6, 7, 9, 11, 6

6 = i_k

min_k

7 = $![(a[i_k] \ge 0)$ && $(min_k > a[i_k])]$

9 = $![[a[i_k] < 0)$ && $(min_k > -a[i_k]))]$

11 = $i_{k+1} = i_{k-1}$

6 = $i_{k+1} = i_{k-1}$

$min_{k+1} = min_k$

$\Rightarrow ![(a[i_k] \ge 0]$ && $(min_k > a[i_k]))$ && $![(a[i_k] < 0)$ && $(min_k > -a[i_k])]$

$[a[i_k] < 0 \;||\; (min_k \le a[i_k])]$ &&

$[a[i_k] \ge 0) \;||\; (min_k \le -a[i_k])]$

$\Rightarrow (a[i_k] < 0)$ && $(min_k \le -a[i_k]) \Rightarrow$ true

$min_k \le |a[i_k]|$

$\Rightarrow$ forall ($i_{k+1}+1 \le t \le n$) : $min_{k+1} \le a[t]$

forall ($i_{k-1}+1 \le t \le n$) : $min_{k+1} \le a[t]$

forall ($i_{k+1} \le t \le n$) : $min_{k+1} \le a[t]$ && $min_{k+1} \le a[i_k]$

forall (~~t~~ $i_k \le t \le n$) : $min_k \le |a[t]|$, loop invariant is correct on termination

(i) $i = 0$

forall ($i+1 \le t \le n$) : $min \le |a[t]|$

forall ($0+1 \le t \le n$) : $min \le |a[t]|$

forall ($1 \le t \le n$) : $min \le |a[t]|$

this is the post condition