

TABLE I. Time series algebra expression mapping rules.

ID	SQL expression	Time Series Algebra	Explanation
1	$T < c$	$T_{vc} = \{(t, v)   t \in \mathbb{T}, v \in (-\infty, c)\}$	Select elements in $T$ where values are $< c$ .
2	$T > c$	$T_{vc} = \{(t, v)   t \in \mathbb{T}, v \in (c, \infty)\}$	Select elements in $T$ where values are $> c$ .
3	$T = c$	$T_{vc} = \{(t, v)   t \in \mathbb{T}, v \in [c, c]\}$	Select elements in $T$ where values are $= c$ .
4	$T \leq c$	$T_{vc} = \{(t, v)   t \in \mathbb{T}, v \in (-\infty, c]\}$	Select elements in $T$ where values are $\leq c$ .
5	$T \geq c$	$T_{vc} = \{(t, v)   t \in \mathbb{T}, v \in [c, \infty)\}$	Select elements in $T$ where values are $\geq c$ .
6	$T \neq c$	$T_{vc} = \{(t, v)   t \in \mathbb{T}, v \neq c\}$	Select elements in $T$ where values are $\neq c$ .
7	<i>true</i>	$T_{vc} = \{(t, v)   t \in \mathbb{T}\}$	Select all elements.
8	<i>false</i>	$T_{vc} = \emptyset$	Select no elements.
9	$T \text{ IS NOT NULL}$	$T_{vc} = \{(t, v)   t \in \mathbb{T}, v \neq \text{null}\}$	Select elements in $T$ where values are not null.
10	$T \text{ IS NULL}$	$T_{vc} = \{(t, v)   t \in \mathbb{T}, v = \text{null}\}$	Select elements in $T$ where values are null.
11	$T \text{ BETWEEN } a \text{ AND } c$	$T_{vc} = \{(t, v)   t \in \mathbb{T}, v \in [a, c]\}$	Select elements in $T$ where values are between $a$ and $c$ .
12	$T \text{ IN } (a, b, c, \dots)$	$T_{vc} = \{(t, v)   t \in \mathbb{T}, v \in (a, b, c \dots)\}$	Select elements in $T$ where values are in $(a, b, c \dots)$ .
13	$+T$	$T = +T$	Select elements in $T$ where values are $= + v$ .
14	$-T$	$T = -T$	Select elements in $T$ where values are $= - v$ .
15	$T_b + T_c$	$T_a = T_b + T_c$	Adds the values of $T_b$ and $T_c$ .
16	$T_b - T_c$	$T_a = T_b - T_c$	Subtracts the value of $T_b$ from $T_c$ .
17	$T_b * T_c$	$T_a = T_b * T_c$	Multiplies the values of $T_b$ and $T_c$ .
18	$T_b / T_c$	$T_a = T_b / T_c$	Divides the value of $T_b$ by $T_c$ .
19	$T_b \bmod T_c$	$T_a = T_b \bmod T_c$	Returns the remainder after dividing $T_b$ by $T_c$ .
20	$T_{bc} \text{ AND } T_{cc}$	$T_{ac} = T_{bc} \cap T_{cc}$	Compute the intersection of $T_{bc}$ and $T_{cc}$ , where $T_{bc}$ and $T_{cc}$ are constraints and $T_{ac}$ is the result.
21	$T_{bc} \text{ OR } T_{cc}$	$T_{ac} = T_{bc} \cup T_{cc}$	Compute the union of $T_{bc}$ and $T_{cc}$ .
22	$\text{NOT } T_{bc}$	$T_{ac} = \neg T_{bc}$	Compute the complement of constraint $T_{bc}$ .
23	$\text{ABS}(T)$	$T = \text{ABS}(T)$	Returns the absolute value of $T$ , which is its non-negative magnitude.
24	$\text{ACOS}(T)$	$T = \text{ACOS}(T)$	Computes the inverse cosine of $T$ , returning an angle (in radians) whose cosine is $T$ .
25	$\text{ASIN}(T)$	$T = \text{ASIN}(T)$	Computes the inverse sine of $T$ , returning an angle (in radians) whose sine is $T$ .
26	$\text{ATAN}(T)$	$T = \text{ATAN}(T)$	Computes the inverse tangent of $T$ , returning an angle (in radians) whose
27	$\text{SQRT}(T)$	$T = \text{SQRT}(T)$	Computes the non-negative square root of $T$ .
28	$W\_SUM(T)$	$T_{ac} = W\_SUM(T)$	Calculate the cumulative sum of columns $T$ within the time window.
29	$W\_COUNT(T)$	$T_{ac} = W\_COUNT(T)$	Counts the number of rows in the time window.
30	$W\_AVG(T)$	$T_{ac} = W\_AVG(T)$	Calculate the arithmetic mean of column $T$ within the time window.
31	$W\_SPEAD(T)$	$T_{ac} = W\_SPEAD(T)$	Calculate the extreme difference (the difference between the maximum and minimum values) of column $T$ within the time window.
32	$W\_STDDEV\_POP(T)$	$T_{ac} = W\_STDDEV\_POP(T)$	Calculate the overall standard deviation (based on the standard deviation of the whole data) of column $T$ within the time window.
33	$W\_VAR\_POP(T)$	$T_{ac} = W\_VAR\_POP(T)$	Calculate the overall variance, i.e., the square of the overall standard deviation, for column $T$ within the time window.
34	$W\_MAX(T)$	$T_{ac} = W\_MAX(T)$	Returns the maximum value of column $T$ within the time window.

35	$W\_MIN(T)$	$T_{ac} = W\_MIN(T)$	Returns the minimum value of column $T$ within the time window.
36	$W\_FIRST(T)$	$T_{ac} = W\_FIRST(T)$	Returns the first non-null value of column $T$ in the time window (in chronological order).
37	$W\_LAST(T)$	$T_{ac} = W\_LAST(T)$	Returns the last non-null value of column $T$ in the time window (in chronological order).
38	$T\_F\_CSUM(T)$	$T_{ac} = T\_F\_CSUM(T)$	Computes the cumulative sum of column $T$ over a time-ordered sequence.
39	$T\_F\_DIFF(T)$	$T_{ac} = T\_F\_DIFF(T)$	Computes the discrete difference between the current value of $T$ and its previous value in the time sequence.
40	$T\_F\_DERIVATIVE(T)$	$T_{ac} = T\_F\_DERIVATIVE(T)$	Computes the rate of change (derivative) of $T$ over time, i.e., the difference in $T$ divided by the time interval.
41	$T\_F\_MAVG(T)$	$T_{ac} = T\_F\_MAVG(T)$	Computes the moving average (rolling average) of column $T$ over the last $N$ time-ordered values.
42	$T\_F\_STATECOUNT(T)$	$T_{ac} = T\_F\_STATECOUNT(T)$	Counts the number of consecutive occurrences where column $T$ meets a specified condition (e.g., $T > \text{threshold}$ ) in the time sequence.
43	$T\_F\_STATEDURATION(T)$	$T_{ac} = T\_F\_STATEDURATION(T)$	Computes the total duration (in specified time unit, e.g., seconds) during which column $T$ satisfies a condition in the time sequence.