FIRE ALARM NOTIFICATION APPLIANCE CIRCUIT VOLTAGE DROP AND LINE LOSS CALCULATIONS

This fact sheet serves as an overview on the calculations required by NFPA 72®, *National Fire Alarm and Signaling Code®,* to determine voltage drops and line loss in notification appliance circuits (NACs), The voltage on a NAC must be sufficient to operate all the notification appliances to ensure they deliver the required output (e.g., sound pressure level, candela output, synchronization). To confirm that the circuits are sized properly, voltage drop or line loss (dB loss) calculations must be completed.

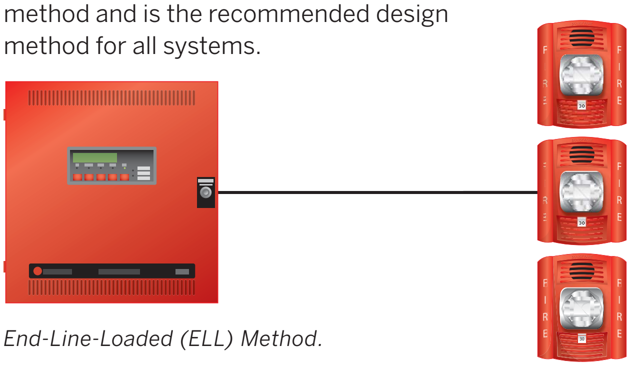
To learn more, view the code requirements and related content at nfpa.org/LiNK.

Calculation Methods

There are two acceptable methods for calculating the voltage drop in DC-power-sourced NACs and line loss in AC-power-sourced NACs, the end-line-loaded method and the point-to-point method.

End-line-loaded (ELL)

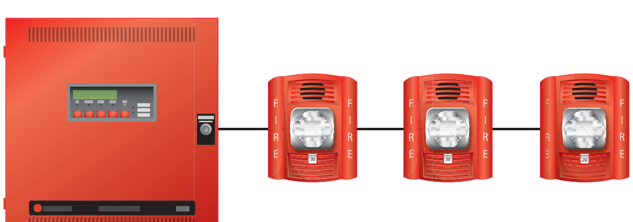
Circuits are designed and tested based on the total circuit resistance and loss. This method assumes that all the appliances are at the end of the circuit and are activated at one time. This is the most conservative method and is the recommended design method for all systems.



End-Line-Loaded (ELL) Method.

Point-to-Point (PTP)

Circuits are designed based on the individual segment and tested on total resistance and loss. This method requires that the designer know the exact wire distance between every appliance. If the installed values are different from the design values, the circuit might not work correctly. This method requires close coordination with the design and field work.

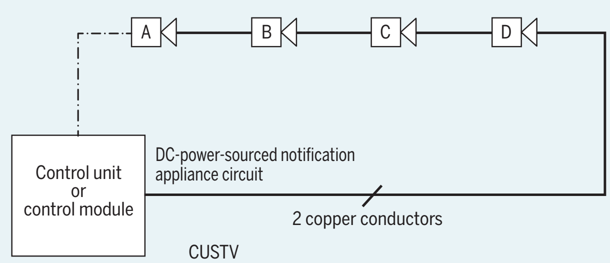


Point-to-Point (PTP) Method.

Conductor Length vs. Circuit Length

These calculations require the use of the entire conductor length in a circuit to calculate either the voltage or dB loss. The length of the circuit run (i.e., the routing path between the control unit and the farthest appliance) is only half of the total conductor length because the total path of the circuit is from the control unit to the last appliance and then back to the control unit.

When calculating loss in a Class A circuit, the circuit length is the distance from the power source to the farthest appliance on the longest side of the circuit, as shown below.



Notes:
(1) Measure from power source to farthest appliance on longest side of circuit.
(2) DC-power-sourced notification appliance circuits are pairs of copper conductors.
(3) Total conductor length (pairs) of DC-power-sourced notification appliance circuit is from the circuit start to the farthest appliance along the longest path of the circuit. In the example above, maximum *path length* (bold line) is from the control unit or control module to Appliance A, through Appliance D, Appliance C, and Appliance B. The maximum *circuit length* is twice the path length. The return (dashed line) is not part of the circuit length calculation.

Class A Measurement for Circuit Length.
(Source: NFPA 72®, *National Fire Alarm and Signaling Code®*, 2025 edition, Figure A.18.3.7.1.4)

DC-Power-Sourced Notification Appliance Circuit Voltage Drop Calculations

DC-power-sourced notification appliance circuits contain appliances that are powered by direct current power such as visible (strobes) and audible (horns) as well as powered devices such as remote annunciators and 4-wire initiating devices such as duct detectors.

A voltage drop calculation is needed to ensure that the resistance from the circuit conductors does not reduce the load voltage at the appliances to less than their minimum listed operating voltage, which is typically 16 VDC.

As noted above, the simplest voltage drop calculation method is the end-line-loaded method. This method assumes all appliances are located at the end of the circuit as shown below.

In that case Ohm's law is used to calculate the voltage drop for the circuit as follows:

$$V_{load} = V_{terminals} - (I_{load}R_{conductors})$$

where:

V_{load} = 16 VDC minimum operating voltage of the appliance (for a nominal 24 VDC regulated appliance)

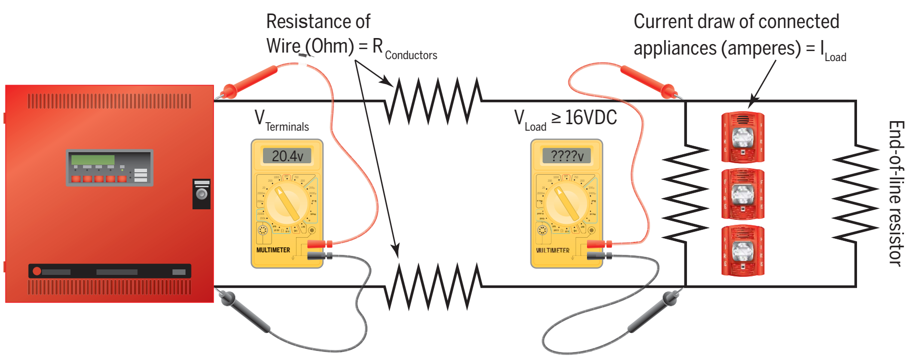
$V_{terminals}$ = 20.4 VDC (unless otherwise specified by the manufacturer and the listing)*

I_{load} = total current draw of the connected appliances [amperes]**

$R_{conductors}$ = total conductor resistance [ohm]

*These examples use a nominal 24 VDC fire alarm system. The end of useful battery life, 20.4 VDC, becomes the starting point for the voltage drop calculations. In some systems, the NAC voltage will be less than the 20.4 VDC battery voltage.

**The I_{load} is the sum of the maximum current draw for all the appliances on the circuit including any control modules that are not integrated with the control unit.



DC-Power-Sourced Notification Appliance Circuit.

The required conductor size can be determined by solving for $R_{conductors}$ and using Table 8, Conductor Properties, of Chapter 9 in NFPA 70®, *National Electrical Code*® (NEC®) with portions extracted below as Table 1. Table 1 provides resistance per 1000 ft and per 1000 m for solid or stranded conductors at 167°F (75°C).

Example

Using a NAC terminal voltage of 20.4 VDC and assuming a V_{load} of 16 VDC and an I_{load} of 5.0 amperes, the resulting (maximum) $R_{conductors}$ is calculated as follows:

$$R_{conductors} = \frac{20.4\ \text{V} - 16\ \text{V}}{5\ \text{amperes}} = 0.88\ \text{ohm}$$

If the circuit were 100 ft (30.5 m) from end to end, the total conductor length would be 200 ft (61 m) (out and back). The maximum permitted resistance per foot would be:

$$\frac{0.88\ \text{ohm}}{200\ \text{ft}} = 0.0044\ \text{ohm/ft, or}$$

4.4 ohm/1000 ft (14.4 ohm/km)

In accordance with Table 1 below, a 14 AWG, stranded, uncoated copper conductor at 167°F (75°C) has a resistance of 3.14 ohm/1000 ft (10.3 ohm/km), which is less than the maximum calculated resistance of 4.4 ohm/1000 ft (14.4 ohm/km). A larger conductor or a reduction in I_{load} would be needed to increase the circuit length.

FIRE ALARM VOLTAGE DROP CALCULATIONS *Continued*

Note that the I_{load} might also be limited by the capability of the control unit output circuit. For example, many power limited NACs have a maximum current output of 2.0 amperes. The length that this circuit could be if wired using 18 AWG, stranded, uncoated copper at 167°F (75°C) [7.95 ohm/1000 ft (26.1 ohm/km) in accordance with Table 8 of NFPA 70] is calculated as follows:

$$\frac{20.4\ \text{V} - 16\ \text{V}}{2\ \text{amperes}} = 2.2\ \text{ohm maximum total conductor resistance}$$

$$\frac{2.2\ \text{ohm}}{0.00795\ \text{ohm/ft}} = 276\ \text{ft maximum conductor length}$$

$$\left\langle \frac{2.2\ \text{ohm}}{0.0261\ \text{ohm/m}} = 84\ \text{m} \right\rangle$$

$$\frac{276\ \text{ft}}{2} = 138\ \text{ft from the control unit to the last appliance}$$

$$\left\langle \frac{84\ \text{m}}{2} = 42\ \text{m} \right\rangle$$

Table 1 - Conductor Properties

			Conductors							Direct-Current Resistance at 75°C (167°F)					
			Stranding			Overall				Copper				Aluminum	
Area				Diameter		Diameter		Area		Uncoated		Coated			
Size (AWG or kcmil)	mm²	Circular mils	Qty	mm	in.	mm	in.	mm²	in.²	ohm/km	ohm/kFT	ohm/km	ohm/kFT	ohm/km	ohm/kFT
18	0.823	1620	1	—	—	1.02	0.040	0.823	0.001	25.5	7.77	26.5	8.08	42.0	12.8
18	0.823	1620	7	0.39	0.015	1.16	0.046	1.06	0.002	26.1	7.95	27.7	8.45	42.8	13.1
16	1.31	2580	1	—	—	1.29	0.051	1.31	0.002	16.0	4.89	16.7	5.08	26.4	8.05
16	1.31	2580	7	0.49	0.019	1.46	0.058	1.68	0.003	16.4	4.99	17.3	5.29	26.9	8.21
14	2.08	4110	1	—	—	1.63	0.064	2.08	0.003	10.1	3.07	10.4	3.19	16.6	5.06
14	2.08	4110	7	0.62	0.024	1.85	0.073	2.68	0.004	0.3	3.14	10.7	3.26	16.9	5.17
12	3.31	6530	1	—	—	2.05	0.081	3.31	0.005	6.34	1.93	6.57	2.01	10.45	3.18
12	3.31	6530	7	0.78	0.030	2.32	0.092	4.25	0.006	6.50	1.98	6.73	2.05	10.69	3.25
10	5.261	10380	1	—	—	2.588	0.102	5.26	0.008	3.984	1.21	4.148	1.26	6.561	2.00
10	5.261	10380	7	0.98	0.038	2.95	0.116	6.76	0.011	4.070	1.24	4.226	1.29	6.679	2.04

Notes:

1. These resistance values are valid **only** for the parameters as given. Using conductors having coated strands, different stranding type, and, especially, other temperatures changes the resistance.
2. Equation for temperature change: $R_2 = R_1 [1 + a (T_2 - 75)]$, where $\alpha_{cu} = 0.00323$, $\alpha_{AL} = 0.00330$ at 75°C.
3. Conductors with compact and compressed stranding have smaller bare conductor diameters than those shown. See Table 5A for actual compact cable dimensions.
4. The IACS conductivities used: bare copper = 100%, aluminum = 61%.
5. Class B stranding is listed as well as solid for some sizes. Its overall diameter and area are those of its circumscribing circle.

Source: NFPA 70®, *National Electrical Code*®, 2023 edition, Chapter 9, portion of Table 8.

FIRE ALARM VOLTAGE DROP CALCULATIONS *Continued*

Table 2 shows maximum circuit lengths (1/2 total conductor length) calculated for a variety of current flows and wire sizes. The table uses end-line-loaded calculations with a low battery starting voltage of 20.4 VDC and assumes a V_{load} of 16 VDC. As previously noted, the NAC terminal voltage and the appliance required voltage may vary from product to product.

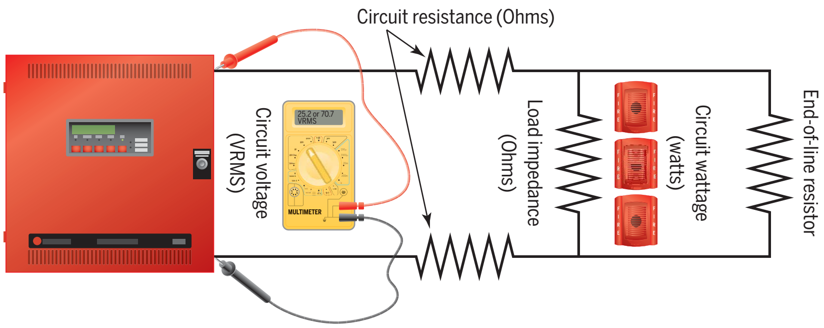
Table 2 - Maximum Circuit Length

Amperes	Maximum Circuit Length with No Safety Factor [ft]									
AWG	**18 Solid**	**18 Strand**	**16 Solid**	**16 Strand**	**14 Solid**	**14 Strand**	**12 Solid**	**12 Strand**	**10 Solid**	**10 Strand**
0.5	566	553	900	882	1433	1401	2280	2222	3636	3548
1.0	283	277	450	441	717	701	1140	1111	1818	1774
1.5	189	184	300	294	478	467	760	741	1212	1183
2.0	142	138	225	220	358	350	570	556	909	887
2.5	113	111	180	176	287	280	456	444	727	710
3.0	94	92	150	147	239	234	380	370	606	591
3.5	81	79	129	126	205	200	326	317	519	507
4.0	71	69	112	110	179	175	285	278	455	444
4.5	63	61	100	98	159	156	253	247	404	394
5.0	57	55	90	88	143	140	228	222	364	355
5.5	51	50	82	80	130	127	207	202	331	323
6.0	47	46	75	73	119	117	190	185	303	296

Source: *National Fire Alarm and Signaling Code Handbook*, 2025 edition, portion of Commentary Table 18.1.
Courtesy of R.P. Schifiliti Association Inc., Reading, MA.

AC-Power-Sourced Notification Appliance Circuit Line Loss Calculations

AC-power-sourced NACs are audible NACs that contain appliances that are powered by alternating current, such as loudspeakers. These circuits might operate at 25 VAC or 70 VAC and are required to be designed such that there is a maximum of 1.0 dB of electrical loss on the circuit and so that the total required wattage on the circuit is not greater than what the amplifier can provide. These calculations are done using a decibel loss (a log ratio of voltages) rather than an absolute value for voltage drop. For more information refer to 18.3.7.2 of NFPA 72®, *National Fire Alarm and Signaling Code*®, 2025 edition, and associated annex sections.



AC-Power-Sourced Notification Appliance Circuit.

$$\text{db circuit loss} = 20 \times \text{Log10} \frac{\text{load impedance}}{\text{load impedance + circuit resistance}}$$

$$\text{load impedance} = \frac{\text{circuit voltage}^2}{\text{circuit wattage}}$$

Load Impedance = the resistance of an AC circuit that includes both the resistance to current as well as the reactance and is measured in ohms; for the sake of this calculation it's best to think of it as the resistance of the load.

Circuit Voltage = the output voltage of the amplifier, which is either 25.2 VRMS or 70.7 VRMS. VRMS stands for root mean square voltage and is the value of an AC signal that is equivalent to the DC voltage that would be required to produce the same heating effects.

Circuit Wattage = the total required wattage of all speakers on the circuit. Each speaker in a fire alarm system is provided with its own transformer so you can adjust the total wattage. The wattage is typically selected at each appliance by moving a jumper. The wattage of a single speaker can typically range from 1/8 watt up to 5 watts. When designing a circuit, it's also important to ensure that the total required wattage of all of the appliances can be supplied by the amplifier.

Circuit Resistance = the resistance of the entire circuit in ohms. This is found by taking the total conductor length of the circuit and multiplying it by the ohms per foot or kilometer. The resistance of conductors can be found in Table 8 of Chapter 9 of the NEC extracted above as Table 1.

Example

Below is an example of an end-line-loaded calculation to determine the dB line loss for a 70.7 VRMS system that has a 19.2 watt load, uses 16 AWG uncoated copper stranded wire and has a total conductor length of 954 ft (0.29 km).

First, the total conductor resistance is calculated using the resistance values found in the Conductor Properties Table of the NEC partially extracted above as Table 1: 16 AWG uncoated stranded copper wire has a resistance of 4.99 ohms per 1000 ft (16.6 ohms per km). Multiply that by the total conductor length to get a total resistance of 4.76 ohms.

Load impedance is calculated as follows:

$$\text{load impedance} = \frac{\text{circuit voltage}^2}{\text{circuit wattage}}$$

$$260.338 = \frac{70.7^2}{19.2}$$

The total dB loss of the circuit is then calculated as follows:

$$\text{db circuit loss} = 20 \times \text{Log10} \frac{\text{load impedance}}{\text{load impedance + circuit resistance}}$$

$$-0.15738 = 20 \times \text{Log10} \frac{260.338}{260.338+4.76}$$

The total dB loss of the circuit is 0.15738, which is compliant because it is less than the maximum of 1 dB. It may be possible to decrease the wire size to 18 AWG.

FIRE ALARM VOLTAGE DROP CALCULATIONS *Continued*

Calculation Software

Most manufacturers of notification appliances provide downloadable, software-based tools to perform voltage drop calculations that significantly simplify the calculation process. The voltage drop and line loss calculations must include all the appliances on the circuit as well as any control modules that are not integrated into the control unit. Even though the calculations may be completed by software, it's important as the designer or plan reviewer to review these calculations to ensure the proper method is being used and the proper inputs are being used in the calculations. The use of software will permit the designer to use the less restrictive point-to-point calculation with more ease, but as discussed earlier, this point-to-point method is less conservative and will require that the field conditions match the inputs used for the calculations.

Learn More

- For more information on NAC voltage drop and line loss calculations, refer to subsection 18.3.7 of the 2025 edition of NFPA 72®, *National Fire Alarm and Signaling Code®*.