Remote Start Circuit Integrity National Electric Code (NEC) 2017 Articles 695.14(F) and 700.10(D)(3)

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SUMMARY

This paper discusses requirements from National Electric Code (NEC) 2017 Articles 695.14 (F) Fire Pumps and 700.10 (D)(3) Emergency Systems, Tentative Interim Amendment (TIA 17-17) and Caterpillar's solution to satisfy the NEC code.

The language of the NEC codes and associated Tentative Interim Amendments are as follows:

Code Language – NEC 2017 Article 695.14 (F) – Fire Pumps[1]

> **Generator Control Panel Wiring Methods.** Control conductors installed between the fire pump power transfer switch and the standby generator suppling the fire pump during the power loss shall be kept entirely independent of all other wiring. The integrity of the generator control wiring shall be continuously monitored. Loss of integrity of the remote start circuit(s) shall initiate visual and audible annunciation of generator malfunction at the generator local and remote annunciator(s) and start the generator(s).
>
> **Tentative Interim Amendment (TIA 17-17).** Control conductors installed between the fire pump power transfer switch and the standby generator suppling the fire pump during the power loss shall be kept entirely independent of all other wiring. The integrity of the generator remote start circuit shall be monitored for broken, disconnected or shorted wires. Loss of integrity—start the generator(s).

Code Language – NEC 2017 Article 700.10 (D) (3) – Emergency Systems[1]

> **Generator Control Panel Wiring Methods.** Control conductors installed between the transfer equipment and the emergency generator shall be kept entirely independent of all other wiring and shall meet the conditions 700.10 (D) (1). The integrity of generator control wiring shall be continuously monitored. Loss of integrity of the remote start circuit(s) shall initiate visual and audible annunciation of generator malfunction at the generator local and remote annunciator(s) and start the generator(s).
>
> **Tentative Interim Amendment (TIA 17-17).** Control conductors installed between the transfer equipment and the emergency generator shall be kept entirely independent of all other wiring and shall meet the conditions 700.10 (D) (1). The integrity of the generator remote start circuit shall be monitored for broken, disconnected or shorted wires. Loss of integrity—start the generator(s).

Note1: Information replicated from the NFPA 70 2017 Edition National Electric Code. Reference Article "695.14 (F)," "700.10(D)(3)" and Tentative Interim Amendment "TIA 17-17 SC 18-8-22 / TIA Log #1357."

Tentative Interim Amendments are in effect for these codes until the next release of the NEC code in 2020, which provides specific updates to these articles. These amendments remove the complexity of the code for its intended use by:

1. Removing the requirement of Full Controls Circuit Integrity and limiting to only Remote Start Circuit Integrity;
2. Removing the requirement of Continuous Monitoring of the Remote Start Circuit; and
3. Removing the requirement of Visual and Audible Annunciation of the Remote Start Circuit (disconnected, open or short).

Caterpillar's Interpretation, Recommendation and Solution

To meet NEC 2017 Article 695.14 (F) Fire Pumps and 700.10 (D)(3) Emergency Systems per the Tentative Interim Amendment as explained in previous section, two items need to be addressed: isolated remote start circuit; and, the integrity of the remote start circuit for disconnected, broken or short wire.

- For all the potential system configurations, wiring isolation can be achieved by running the remote start signal wires in a separate conduit or run as accepted by your local AHJ (Authority Having Jurisdiction).
- Circuit integrity for disconnected, open or short remote start wire can be achieved by using a form C-Relay and an additional input for integrity beside the dedicated remote start digital input. Depending on the system configurations explained below for Cat® EMCP 4x generator set controllers and switchgear, each may require a separate set of form C-Relay and a digital input for their corresponding wiring loops.

The following paragraphs establish a foundation by providing a basic understanding of terms, conventions, requirements and a truth table.

- NO = Normally Open, NC = Normally Closed
- NO Loop is the wiring loop from common going through the NO contacts
- NC Loop is the wiring loop from common going through the NC contacts
- Changeover Form C - Relay/Contacts - single pole double throw (SPDT) used for the integrity circuit
- Wiring Integrity Truth Table

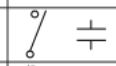
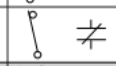
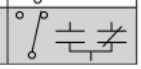
Contact Name	Short Form	DIN / IEC Symbol	UL / CSA Symbol
Normally Open	NO, Form A		
Normally Closed	NC, Form B		
Changeover	CO, Form C, SPDT		

Figure 1: Form A, B and C-Relays. Remote Start Signal Integrity requires Form C-Relay.

Description	Relay Contact Status NO : NC	Remote Start Wiring Loops NO Loop : NC Loop	Digital Input Logical State DI-Start : DI-Integrity	Generator Set State / Comments
Normal Operation - Generator Set in Standby	Open : Closed	Good : Good	0 : 1	• Start Signal – Inactive • No Wiring Failure Event
Normal Operation - Generator Set Starts	Closed : Open	Good : Good	1 : 0	• Start Signal – Active • Normal Generator Set Starts • No Wiring Failure Event
Generator Set Starts with Event - Wire Short	-	Short	1 : 1	• Start Signal – Active • Generator Set Starts with wiring Failure Event • EMCP4x SPN=4002, FMI=2 / 14
Generator Set Starts with Event - Wire Open, Disconnected or Broken	-	Open / Disconnected / Broken	0 : 0	• Start Signal – Active • Generator Set Starts with wiring Failure Event • EMCP4x SPN=4002, FMI=2 / 14

Table 1: Wiring Integrity Truth Table

The following controllers, software and Cat® ET are required for a generator set equipped with a Cat EMCP 4x controller:

- Cat EMCP 4.2B, 4.3 or 4.4 controller with Prod 4.8 software or later
- Cat EMCP 4.2 controller with Prod 4.4.3 software or later
- 2017B or later Cat ET is required, otherwise program with display
- Cat EMCP 4x digital “integrity” input active state must be configured as “active low”

SYSTEM CONFIGURATIONS

While the remote circuit isolation requirement is common to all configurations, there are differences in remote start circuit diagrams depending on the system configurations described below.

Even though the remote start circuit diagrams differ, the fundamental aspect of the truth tables remains the same across these various system configurations explained in the sections below.

These various system configurations require circuit diagrams and truth tables to achieve remote start circuit integrity to satisfy NEC 2017 code:

A. Single Generator Set and ATS
B. Single Generator Set and Multiple ATS
C. Single Generator Set, ATS, and Switchgear
D. Multiple Generator Sets, Multiple ATS, and Switchgear

System Configuration A: Single Generator Set and ATS

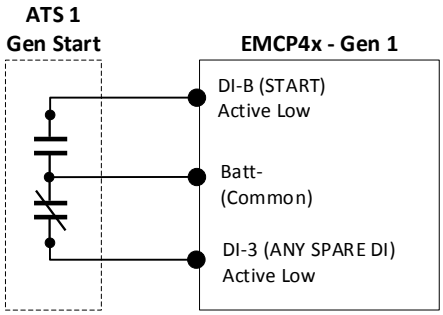


Figure 2: System Configuration A – Single Generator Set and ATS

ATS Generator Set Start Status NO : NC	Remote Start Wiring Loops NO Loop : NC Loop	Digital Input Logical State DI-Start : DI-Integrity	Generator Set State / Comments
Open : Closed	Good : Good	0 : 1	Generator Set Standby / Normal Operation
Closed : Open	Good : Good	1 : 0	Generator Set Starts / Normal Transfer
Open : Closed	Open : Good	0 : 1	Generator Set Standby / see comments below
Closed : Open	Open : Good	0 : 0	Generator Set Starts with event / Wiring failure Open *Generator Set does not start intially under wire open condition in NO Loop; however Generator Set starts with wiring failure event when the ATS sends a Generator Set start signal opening the NC contact via Good NC Loop*
Open : Closed	Good : Open	0 : 0	Generator Set Starts with event / Wiring Failure Open
Open : Closed	Open : Open	0 : 0	Generator Set Starts with event / Wiring Failure Open
Open : Closed	Short : Good	1 : 1	Generator Set Starts with event / Wiring Failure Short
Open : Closed	Good : Short	0 : 1	Generator Set Standby / see comments below
Closed : Open	Good : Short	1 : 1	Generator Set Starts with event / Wiring failure Short *Generator Set does not start intially under wire short condition in NC Loop; however Generator Set starts with wiring failure event when the ATS sends a Generator Set start signal closing the NO contact via Good NO Loop*
Open : Closed	Short : Short	1 : 1	Generator Set Starts with event / Wiring Failure Short

Configuration B: Single Generator Set and Multiple ATS

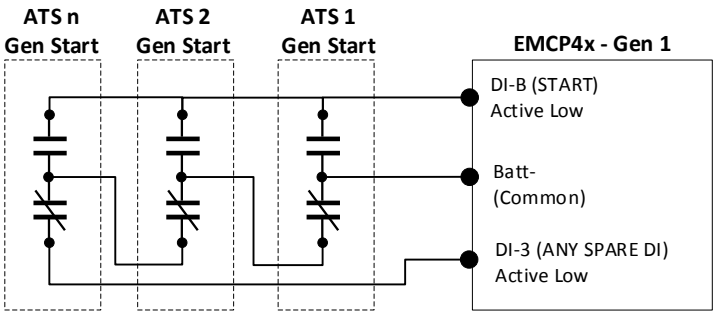


Figure 3: System Configuration B – Single Generator Set and Multiple ATS

To simplify the truth table for readability purposes NO and NC contacts below are cumulatively representing multiple ATS.

Multiple ATS Generator Set Start Status NO : NC	Remote Start Wiring Loops NO Loop : NC Loop	Digital Input Logical State DI-Start : DI-Integrity	Generator Set State / Comments
Open : Closed	Good : Good	0 : 1	**Generator Set Standby / Normal Operation**
Closed : Open	Good : Good	1 : 0	**Generator Set Starts / Normal Transfer**
Open : Closed	Open : Good	0 : 1	Generator Set Standby / see comments below
Closed : Open	Open : Good	0 : 0	Generator Set Starts with event / Wiring failure Open *Generator Set does not start intially under wire open condition in NO Loop; however Generator Set starts with wiring failure event when the ATS sends a Generator Set start signal opening the NC contact via Good NC Loop*
Open : Closed	Good : Open	0 : 0	Generator Set Starts with event / Wiring Failure Open
Open : Closed	Open : Open	0 : 0	Generator Set Starts with event / Wiring Failure Open
Open : Closed	Short : Good	1 : 1	Generator Set Starts with event / Wiring Failure Short
Open : Closed	Good : Short	0 : 1	Generator Set Standby / see comments below
Closed : Open	Good : Short	1 : 1	Generator Set Starts with event / Wiring failure Short *Generator Set does not start intially under wire short condition in NC Loop; however Generator Set starts with wiring failure event when the ATS sends a Generator Set start signal closing the NO contact via Good NO Loop*
Open : Closed	Short : Short	1 : 1	Generator Set Starts with event / Wiring Failure Short

System Configuration C: Single Generator Set, ATS and Switchgear

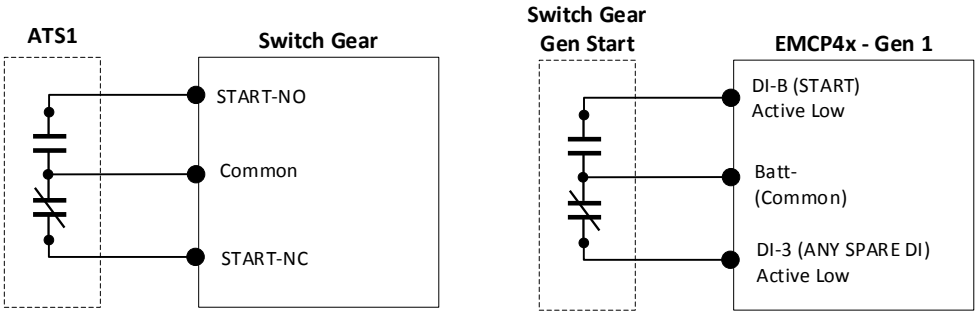


Figure 4: System Configuration C – Single Generator Set, ATS and Switchgear

Switchgear Generator Set Start Status NO : NC	Remote Start Wiring Loops NO Loop : NC Loop	Digital Input Logical State DI-Start : DI-Integrity	Generator Set State / Comments
Open : Closed	Good : Good	0 : 1	**Generator Set Standby / Normal Operation**
Closed : Open	Good : Good	1 : 0	**Generator Set Starts / Normal Transfer**
Open : Closed	Open : Good	0 : 1	Generator Set Standby / see comments below
Closed : Open	Open : Good	0 : 0	Generator Set Starts with event / Wiring failure Open *Generator Set does not start intially under wire open condition in NO Loop; however Generator Set starts with wiring failure event when the Switchgear sends a Generator Set start signal opening the NC contact via Good NC Loop*
Open : Closed	Good : Open	0 : 0	Generator Set Starts with event / Wiring Failure Open
Open : Closed	Open : Open	0 : 0	Generator Set Starts with event / Wiring Failure Open
Open : Closed	Short : Good	1 : 1	Generator Set Starts with event / Wiring Failure Short
Open : Closed	Good : Short	0 : 1	Generator Set Standby / see comments below
Closed : Open	Good : Short	1 : 1	Generator Set Starts with event / Wiring failure Short *Generator Set does not start intially under wire short condition in NC Loop; however Generator Set starts with wiring failure event when the Switchgear sends a Generator Set start signal closing the NO contact via Good NO Loop*
Open : Closed	Short : Short	1 : 1	Generator Set Starts with event / Wiring Failure Short

ATS Switchgear Start Status NO : NC	Remote Start Wiring Loops NO Loop : NC Loop	Digital Input Logical State DI-Start : DI-Integrity	Generator Set State / Comments
Open : Closed	Good : Good	0 : 1	Generator Set Standby / Normal Operation
Closed : Open	Good : Good	1 : 0	Generator Set Starts / Normal Transfer
Open : Closed	Open : Good	0 : 1	Generator Set Standby / see comments below
Closed : Open	Open : Good	0 : 0	Generator Set Starts with event / Wiring failure Open *Generator Set does not start intially under wire open condition in NO Loop ; however Generator Set starts with wiring failure event when the Switchgear sends a Generator Set start signal opening the NC contact via Good NC Loop*
Open : Closed	Good : Open	0 : 0	Generator Set Starts with event / Wiring Failure Open
Open : Closed	Open : Open	0 : 0	Generator Set Starts with event / Wiring Failure Open
Open : Closed	Short : Good	1 : 1	Generator Set Starts with event / Wiring Failure Short
Open : Closed	Good : Short	0 : 1	Generator Set Standby / see comments below
Closed : Open	Good : Short	1 : 1	Generator Set Starts with event / Wiring failure Short *Generator Set does not start intially under wire short condition in NC Loop; however Generator Set starts with wiring failure event when the Switchgear sends a Generator Set start signal closing the NO contact via Good NO Loop*
Open : Closed	Short : Short	1 : 1	Generator Set Starts with event / Wiring Failure Short

System Configuration D: Multiple Generator Sets, Multiple ATSs and Switchgear

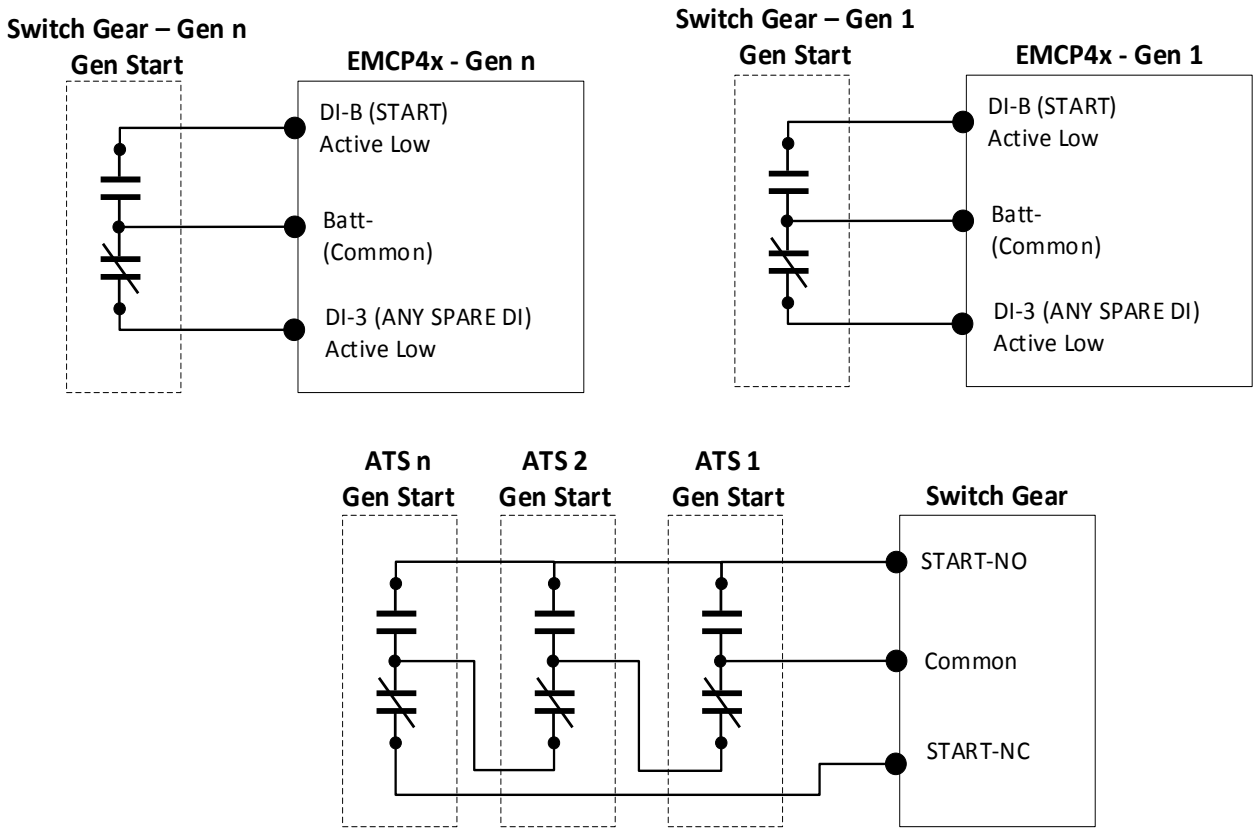


Figure 5: System Configuration D – Multiple Generator Sets, Multiple ATS and Switchgear

To simplify the truth table for readability purposes NO and NC contacts below are cumulatively representing multiple generator sets and ATS.

Switchgear Multiple Generator Set Start Status NO : NC	Remote Start Wiring Loops NO Loop : NC Loop	Digital Input Logical State DI-Start : DI-Integrity	Generator Set State / Comments
Open : Closed	Good : Good	0 : 1	**Generator Set Standby / Normal Operation**
Closed : Open	Good : Good	1 : 0	**Generator Set Starts / Normal Transfer**
Open : Closed Closed : Open	Open : Good Open : Good	0 : 1 0 : 0	Generator Set Standby / see comments below Generator Set Starts with event / Wiring failure Open *Generator Set does not start intially under wire open condition in NO Loop; however Generator Set starts with wiring failure event when the Switchgear sends a Generator Set start signal opening the NC contact via Good NC Loop*
Open : Closed	Good : Open	0 : 0	Generator Set Starts with event / Wiring Failure Open
Open : Closed	Open : Open	0 : 0	Generator Set Starts with event / Wiring Failure Open
Open : Closed	Short : Good	1 : 1	Generator Set Starts with event / Wiring Failure Short
Open : Closed Closed : Open	Good : Short Good : Short	0 : 1 1 : 1	Generator Set Standby / see comments below Generator Set Starts with event / Wiring failure Short *Generator Set does not start intially under wire short condition in NC Loop; however Generator Set starts with wiring failure event when the Switchgear sends a Generator Set start signal closing the NO contact via Good NO Loop*
Open : Closed	Short : Short	1 : 1	Generator Set Starts with event / Wiring Failure Short
Multiple ATS Switchgear Start Status NO : NC	**Remote Start Wiring Loops NO Loop : NC Loop**	**Digital Input Logical State DI-Start : DI-Integrity**	**Generator Set State / Comments**
Open : Closed	Good : Good	0 : 1	Generator Set Standby / Normal Operation
Closed : Open	Good : Good	1 : 0	Generator Set Starts / Normal Transfer
Open : Closed Closed : Open	Open : Good Open : Good	0 : 1 0 : 0	Generator Set Standby / see comments below Generator Set Starts with event / Wiring failure Open *Generator Set does not start intially under wire open condition in NO Loop ; however Generator Set starts with wiring failure event when the Switchgear sends a Generator Set start signal opening the NC contact via Good NC Loop*
Open : Closed	Good : Open	0 : 0	Generator Set Starts with event / Wiring Failure Open
Open : Closed	Open : Open	0 : 0	Generator Set Starts with event / Wiring Failure Open
Open : Closed	Short : Good	1 : 1	Generator Set Starts with event / Wiring Failure Short
Open : Closed Closed : Open	Good : Short Good : Short	0 : 1 1 : 1	Generator Set Standby / see comments below Generator Set Starts with event / Wiring failure Short *Generator Set does not start intially under wire short condition in NC Loop; however Generator Set starts with wiring failure event when the Switchgear sends a Generator Set start signal closing the NO contact via Good NO Loop*
Open : Closed	Short : Short	1 : 1	Generator Set Starts with event / Wiring Failure Short

Note: When wiring failure happens in the Switchgear-ATS wiring loop, the event will be generated and displayed at the Switchgear. However, if the wiring failure happens in ATS-Generator Set or Switchgear-Generator Set wiring loop, the event will be generated and displayed at the Generator Set. Regardless of any wiring loop failure, the ultimate result will be a "Generator Set Start" with start wiring failure event.

Remote Start Wiring Integrity Configuration for Cat EMCP 4x Generator Set Controller

Cat EMCP 4x provides two parameters for Integrity Digital Input that can be configured for any available digital input. ENG REMOTE START (INVERTED) is used for single and GRP REMOTE START (INVERTED) is used for multiple ATS, shown in Figure 6 with associated wiring failure events and shown in Figures 7 and 8.

Figure 6: Cat EMCP 4x Digital Input configuration screenshot

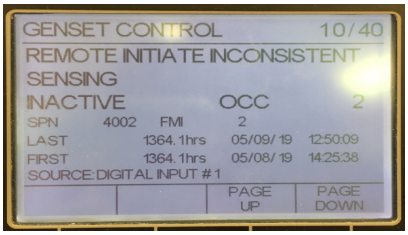
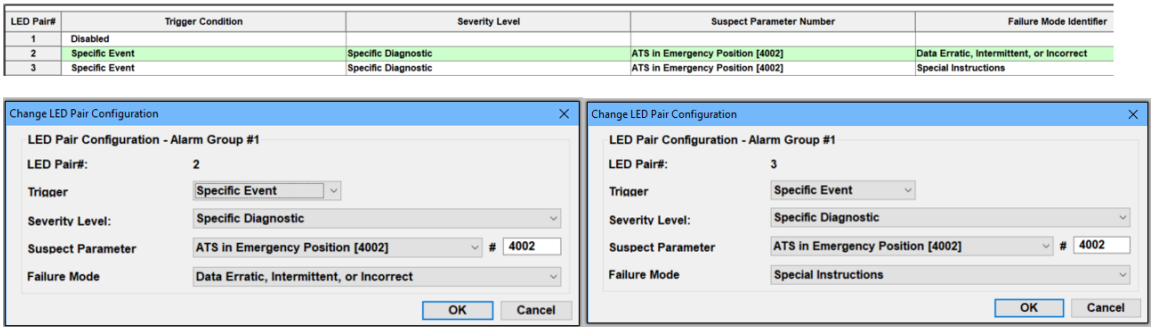


Figure 7: Remote Start Wiring Failure Event Cat EMCP 4x for Single ATS (SPN=4002, FMI=2)

Figure 8: Remote Start Wiring Failure Event Cat EMCP 4x for multiple ATS (SPN=4002, FMI=14)

Furthermore, these events can be annunciated on a custom annunciator.



LED Pair#	Trigger Condition	Severity Level	Suspect Parameter Number	Failure Mode Identifier
1	Disabled			
2	Specific Event	Specific Diagnostic	ATS in Emergency Position [4002]	Data Erratic, Intermittent, or Incorrect
3	Specific Event	Specific Diagnostic	ATS in Emergency Position [4002]	Special Instructions

Figure 9: EMCP4x Custom Annunciator Configuration screenshots for single and multiple ATS respectively

CONCLUSION

With a good understanding of the NEC code requirement, the recommendation and solution provided in this white paper makes it comfortable and straightforward to adapt and comply with the NEC code, while the final authority to approve is AHJ.

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