

A hotel lobby that looks steady to the eye, and the same lobby on a phone screen: flicker stripes the camera catches.

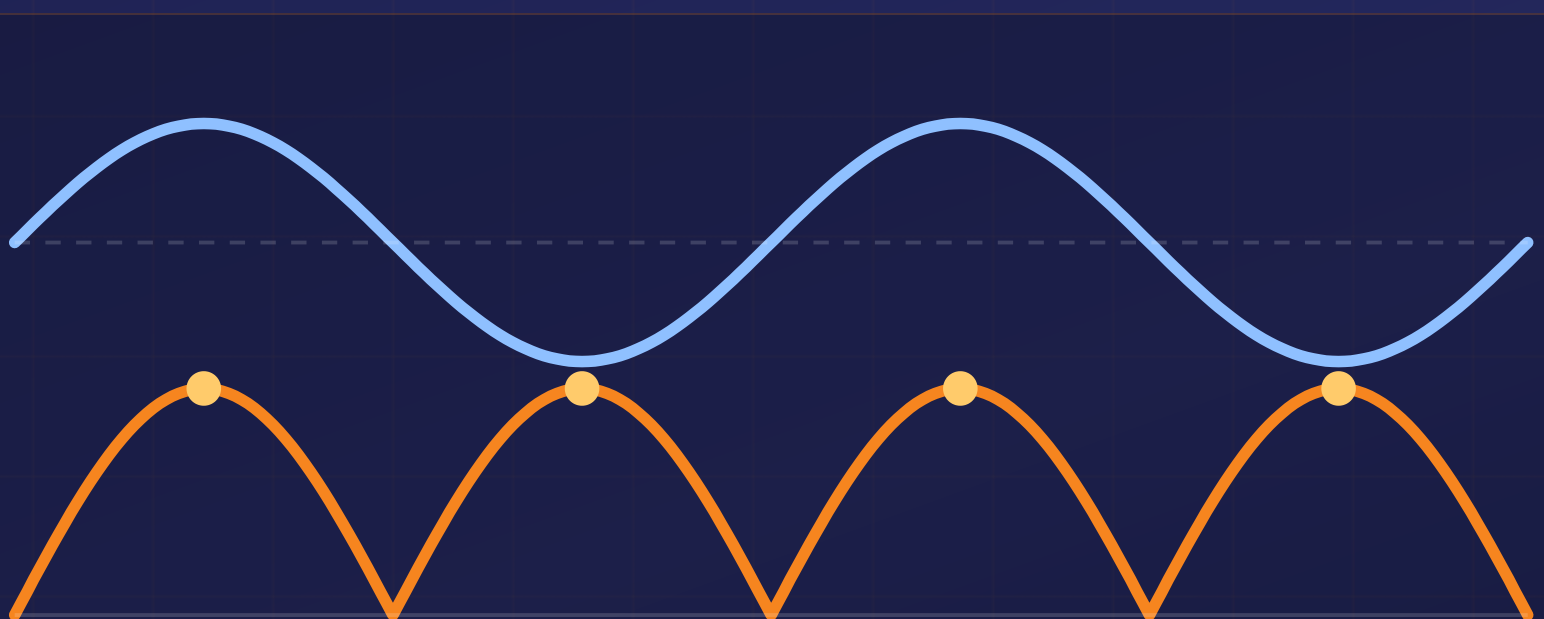
NLC ACADEMY · EPISODE 21

Your eye averages it away. Your camera does not.

Flicker is one of the lighting qualities most often photographed and least often specified. Here is what to measure, and why a Saudi project should not simply copy a European 50 Hz rule of thumb.

WHERE IT COMES FROM

On a 60 Hz grid, mains-related LED ripple commonly appears at 120 Hz



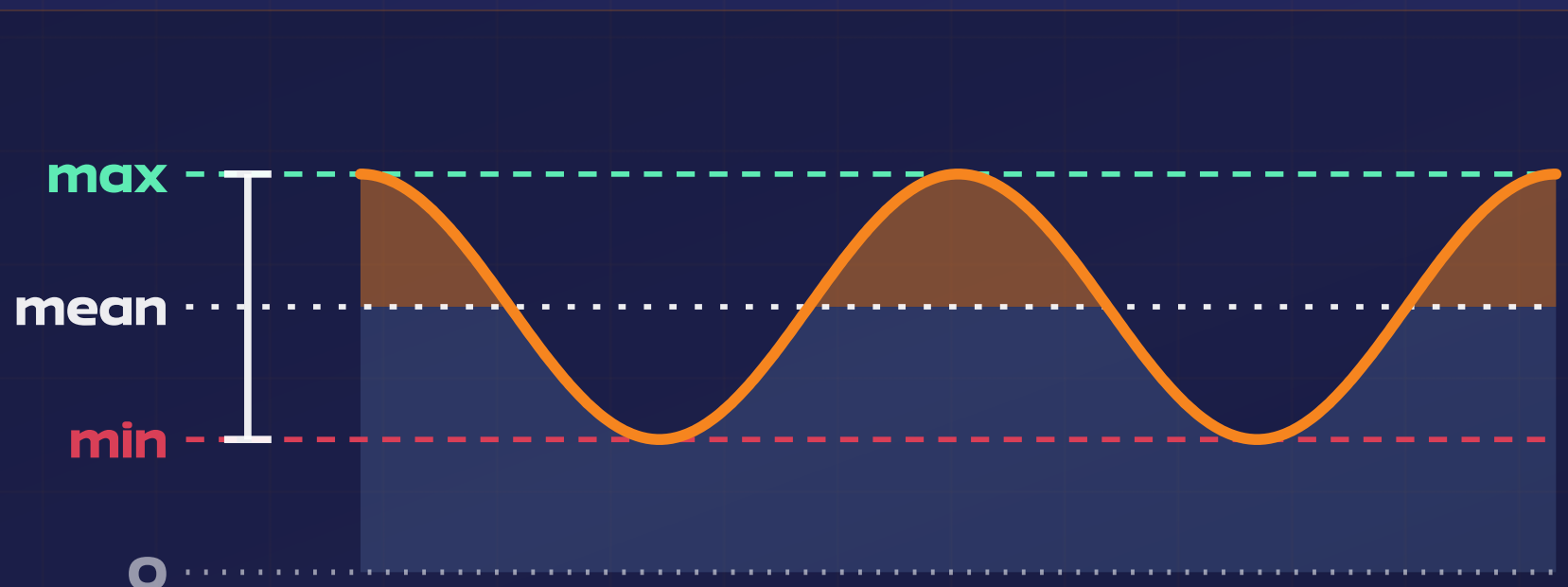
1 mains cycle = 2 light pulses

1. A full-wave rectifier produces two peaks per mains cycle, so mains-related ripple can appear at **twice** the line frequency: 120 Hz here, one period every 8.333 ms. [1][9]
2. A strong 60 Hz component usually indicates asymmetric or half-wave behaviour rather than normal full-wave ripple. [1]

120 Hz is common, not inevitable. A well-filtered driver can reduce this modulation substantially. Many commonly quoted European examples assume a 50 Hz supply and a 100 Hz ripple.

THE TWO OLD NUMBERS

What percent flicker and flicker index actually measure



percent flicker = 100 x (max - min) / (max + min) = 50%
flicker index = area 1 / (area 1 + area 2) = 0.16

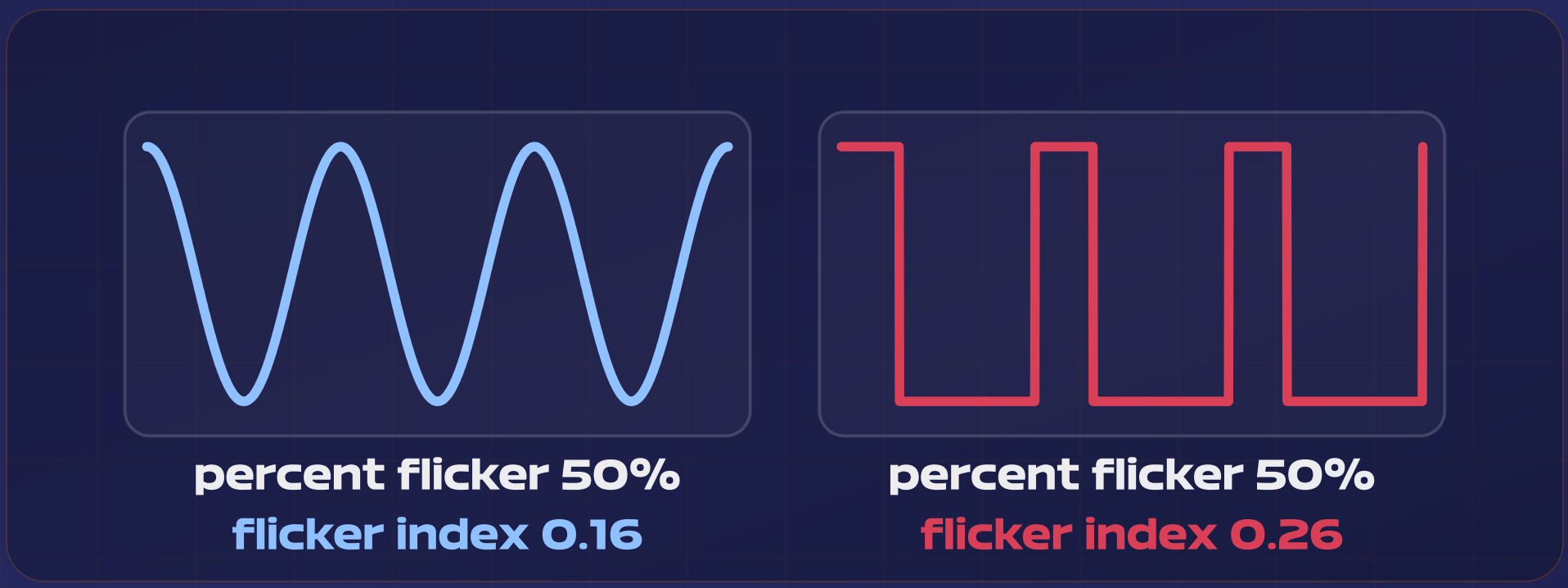
1. **Percent flicker**, also called percent amplitude modulation, = 100 x (max - min) / (max + min). A percentage, not a fraction. [1]

2. **Flicker index** = the area of one cycle above the average level, divided by the total area under the curve. [1]

Neither metric includes frequency. Both are read from a single cycle, so they cannot tell you how fast it repeats. [8]

WHY ONE NUMBER IS NOT ENOUGH

Same modulation depth. Different waveform. Different index.



percent flicker 50%
flicker index 0.16

percent flicker 50%
flicker index 0.26

Both waveforms modulate 50%. The pulse scores a flicker index of 0.26 against the sine's 0.16, because the index reads the shape between the extremes.

Percent flicker alone cannot describe temporal behaviour: 5% at 60 Hz is more than three times the IEEE low-risk line, while 5% at 120 Hz sits inside it. For a meaningful temporal light modulation (TLM) assessment, report modulation depth, frequency and waveform together. [1]

THE RISK PLANE

IEEE 1789 is a plane, not a number



9.6%
Low risk
at 120 Hz, from Mod% < 0.08 x f [1]

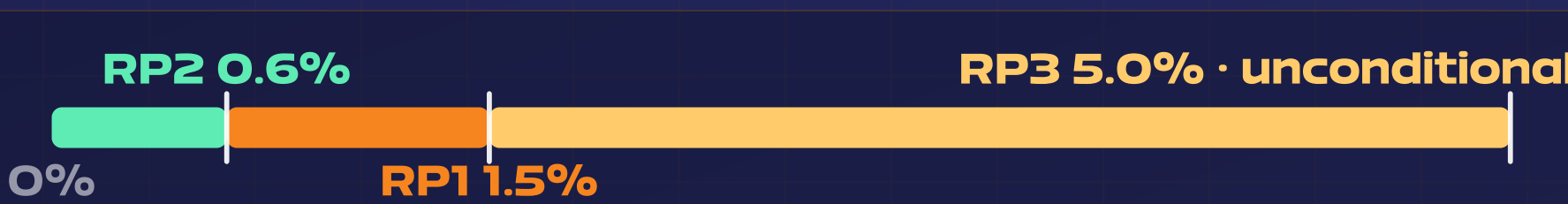
4.0%
No observable effect
at 120 Hz, from Mod% < 0.0333 x f [1]

5%
Strict limit below 90 Hz
RP3, the only one without "If it is desired" [1]

IEEE 1789 gives frequency-dependent recommended practices, not one universal percentage. Its 8% and 9.6% both come from the low-risk line, Mod% < 0.08 x f, at 100 Hz and 120 Hz. Copying the 100 Hz figure into a 120 Hz application tightens it by 16.7% against the standard's own line. [1]

READ THE STANDARD, NOT THE BLOG

Three recommended practices. Only one is unconditional.



at 60 Hz the only unconditional line is the loosest

Low risk, below 90 Hz
RP1, opens "If it is desired" [1]
0.025 x f

Low risk, 90 Hz to 1250 Hz
RP1, second segment [1]
0.08 x f

No observable effect, 90 Hz to 3000 Hz
RP2, about 2.4x stricter; 0.01 x f below 90 Hz [1]
0.0333 x f

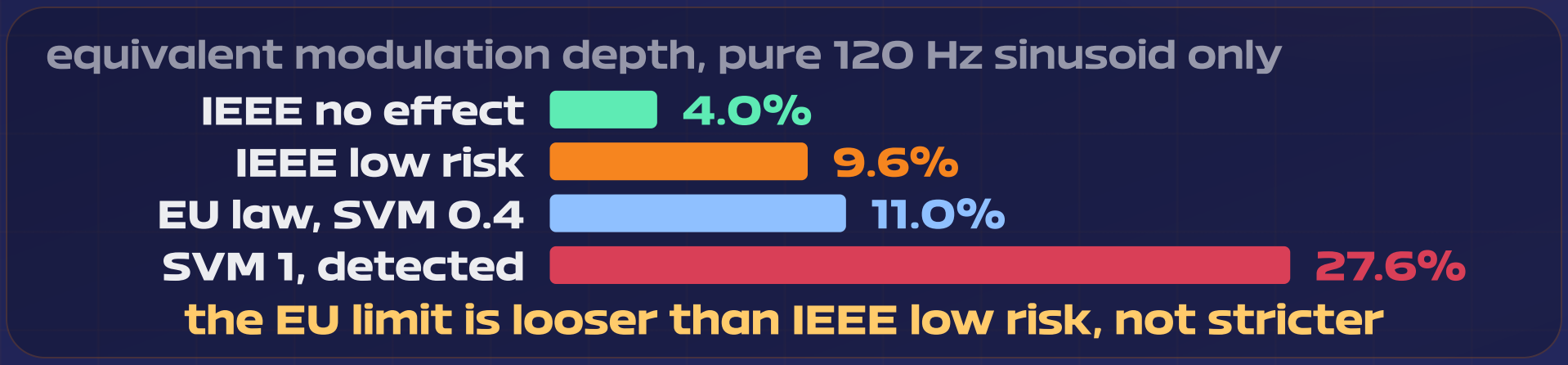
Seizure prevention, below 90 Hz
RP3, the only one without "If it is desired": a strict rule [1]
< 5%

Full-depth PWM is low risk only above 1250 Hz, where 0.08 x f reaches 100%. A driver under 9.6% at 120 Hz needs no kilohertz switching. [1]

IEEE 1789-2015 became Inactive-Reserved on 26 March 2026, content unchanged. Cite the 2015 edition and the number, not generic compliance. [1]

WHAT THE MODERN NUMBERS MEAN

Two thresholds that are routinely read backwards



Not "imperceptible"

PstLM = 1: an average observer's visibility threshold. A ceiling, not a badge. [3]

PstLM = 1

Not "no effect"

SVM = 1: approximately the average observer's visibility threshold, under the defined test conditions. [2][13]

SVM = 1

A legal limit in its scope

SVM ≤ 0.4 at full load: EU ecodesign law since 1 September 2024. A regulatory threshold, not a definition of flicker-free. [4]

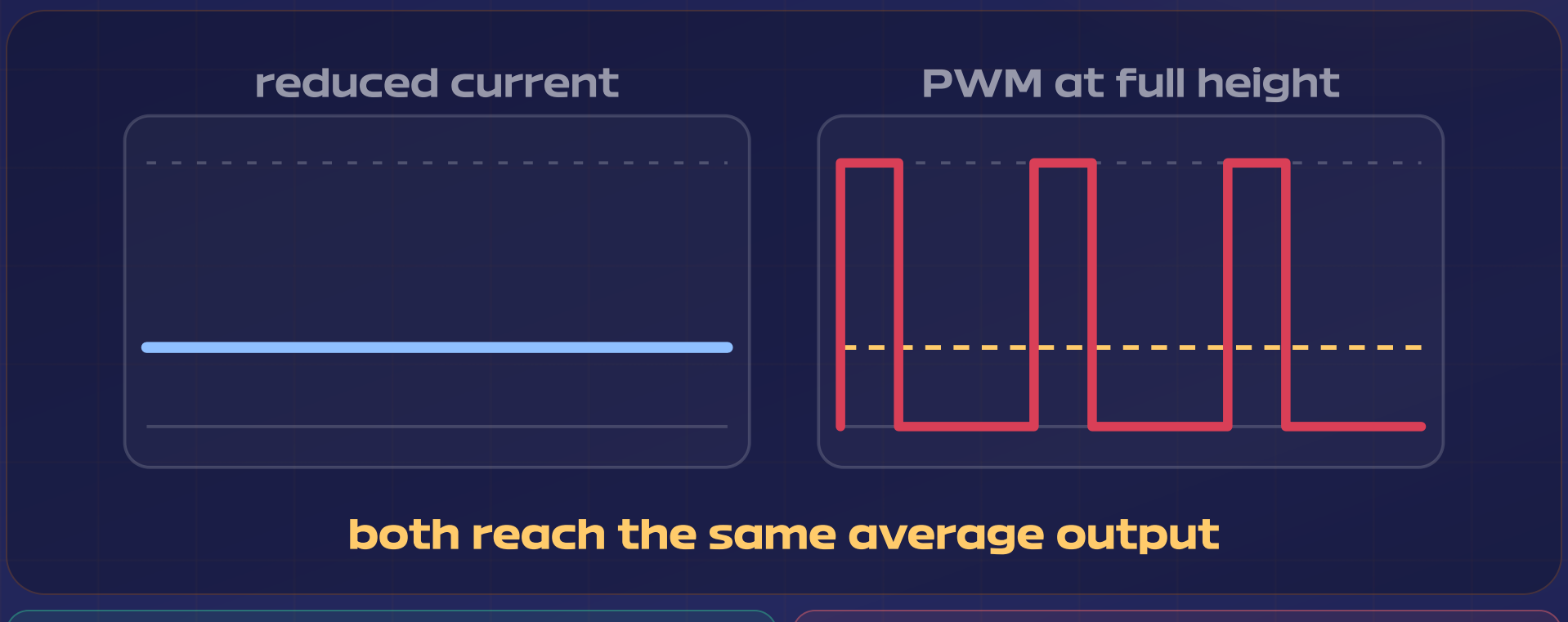
SVM ≤ 0.4

Pure 120 Hz sinusoid only: SVM = 1 corresponds to about 27.6% modulation and SVM = 0.4 to about 11.0%. [2]

Real waveforms carry harmonics that shift this conversion, so measure SVM and PstLM rather than converting. IEC TR 61547-1 and IEC TR 63158 set methods, not limits. [3][13][14]

HISTORICAL CALIFORNIA TEST DATA, 2014

Dimming can expose what a full-output test misses



both reach the same average output

13
of 25 passed
at full output and at 25% output, reported 2016 [7]

12
of 25 failed
at 100%, at 25%, or both [7]

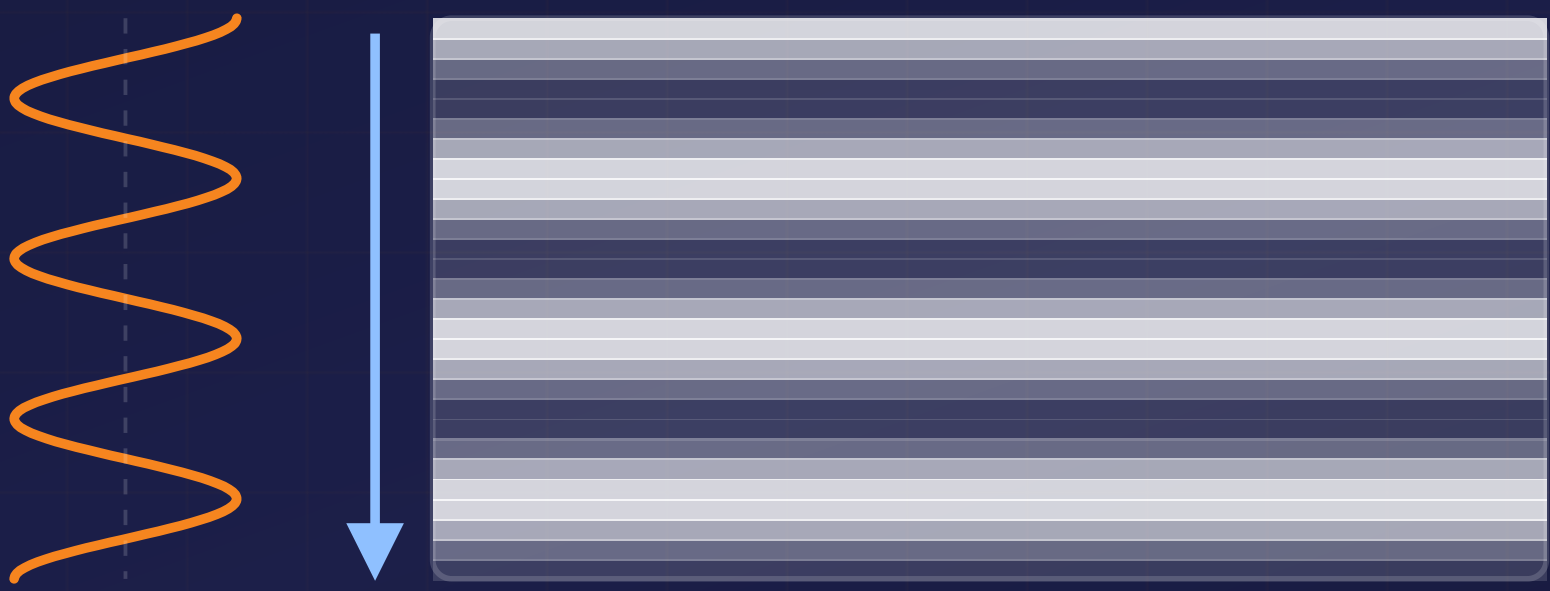
PWM dimming creates high modulation depth by design, while reducing the drive current adds little modulation of its own. [1] On PAR38 lamps, adding a phase-cut dimmer at full output raised the measured flicker index by up to 0.15, and dimmed lamps usually got worse. [12]



A dimmable LED head, and the camera that sees what dimming does.

ON CAMERA

Why a single still photo can show you the waveform



one frame, one row at a time

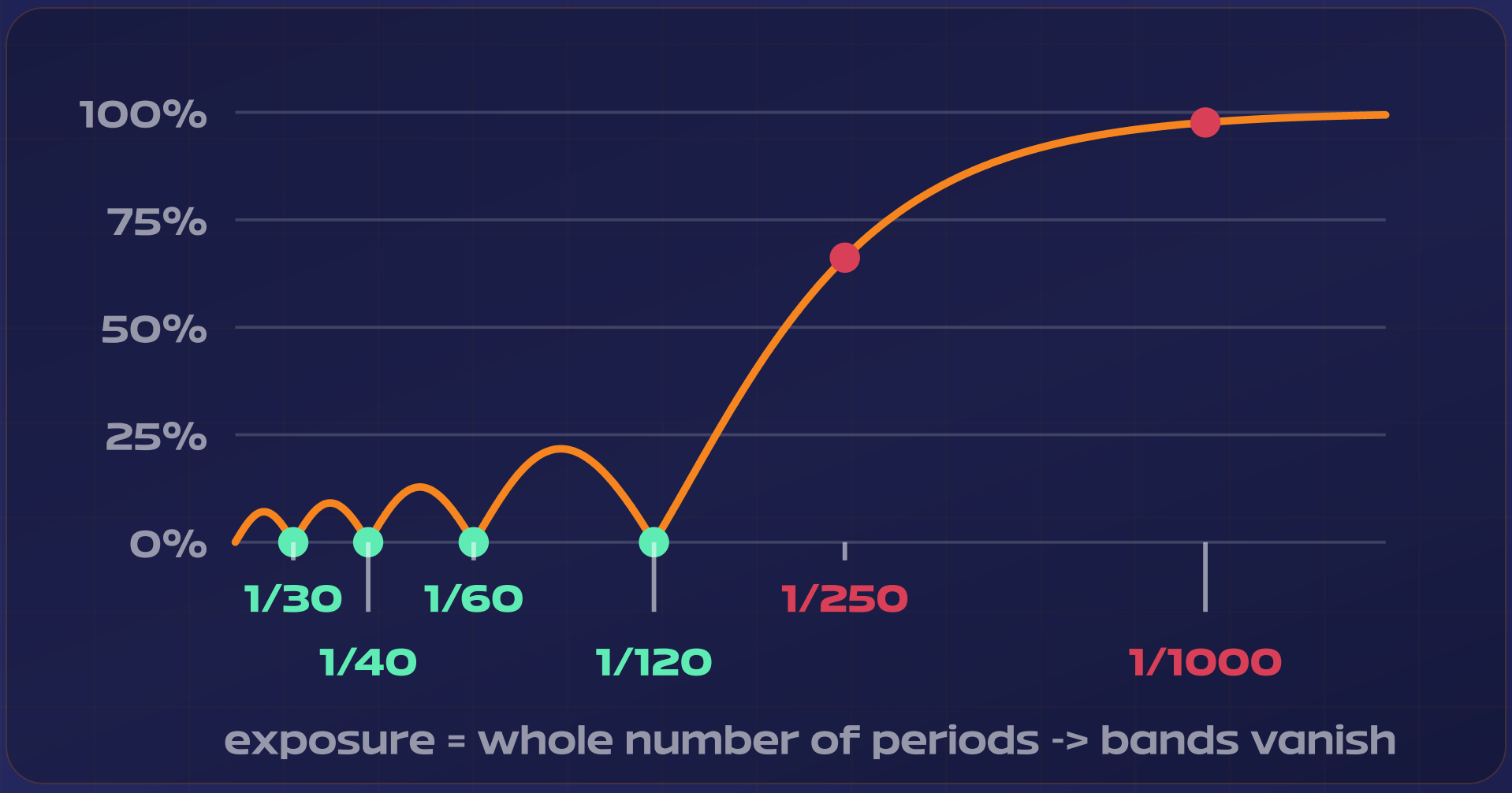
1. Many CMOS rolling-shutter cameras expose or read the image row by row. While the sensor scans, the light keeps pulsing, so its waveform is written down the frame as bands.

2. The number of bands is roughly the modulation frequency times the sensor readout time, so a higher frequency gives finer bands and, at a given exposure, usually shallower ones.

A phone camera can reveal temporal light modulation. It cannot certify its absence. A clean clip is not a compliance test.

ILLUSTRATIVE, IDEAL 120 Hz SINUSOID

The exposure has to contain a whole number of modulation periods



1/30	1/40	1/60	1/120	1/250
0%	0%	0%	0%	66%

Percentages show the share of the modulation surviving one exposure, for an ideal 120 Hz sinusoid. 1/250 is the trap: close to half a period, so about 66% survives. Real drivers carry harmonics and other frequencies, and cameras differ, so the principle holds while the exact percentages will differ.

WHO ACTUALLY REQUIRES ANYTHING

Test methods define how to measure. Regulations and project specifications set the limits.



of these three, Title 24 checks dimmed output

EU ecodesign (regulation)
At full load, for mains light sources in scope. Dimmed operation is not covered. [4]

PstLM ≤ 1
SVM ≤ 0.4

California Title 24, JA8 (code)
Reduced flicker operation, required at 100% and at 20% output, per JA10. It checks dimmed operation. [5]

< 30%
< 200 Hz

WELL v2 L08.2 (optimization, 2 points)
One of three routes; the others are Title 24 reduced flicker or IEEE 1789 RP1 to RP3. [6]

PstLM ≤ 1
SVM ≤ 0.6

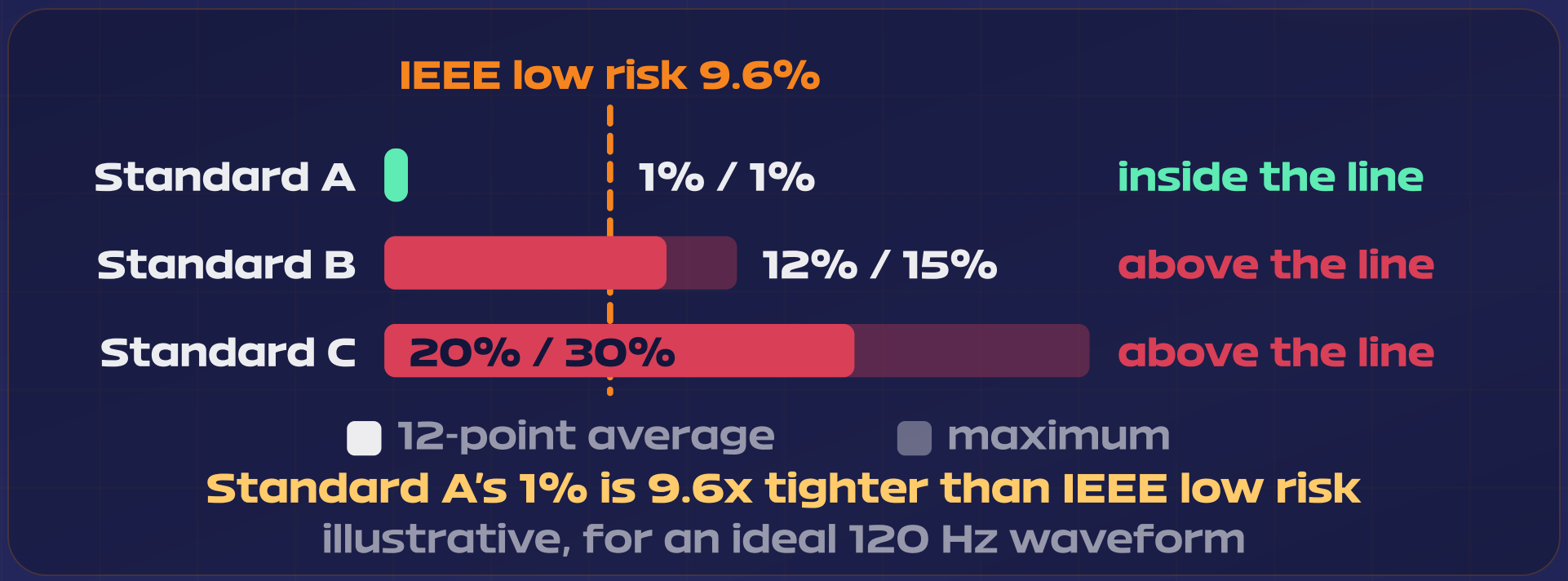
SASO 2870, 2902, 2927 · LEED v4.1 · Mostadam
No explicit PstLM, SVM or modulation limit found in the documents reviewed. [10]

not found

In Saudi projects, flicker performance often rests on the specification. "SASO approved" alone does not describe it.

BROADCAST AND HIGH-SPEED CAMERA APPLICATIONS

For broadcast stadium lighting, FIFA gives one of the clearest project limits



1% / 1%	12% / 15%	20% / 30%
FIFA Standard A	**FIFA Standard B**	**FIFA Standard C**
12-point average and maximum [11]	average / maximum [11]	average / maximum [11]

1. Vertical illuminance at 1 m height on the 90 and 270 degree planes, six pitch positions, twelve readings averaged. [12]
2. FIFA's flicker factor, (Emax - Emin) / (Emax + Emin) x 100, is percent flicker by another name; its mean-referenced alternative agrees only for a symmetric waveform. [12]

A broadcast criterion, not a general-lighting limit. FIFA measures the pitch and IEEE 1789 recommends by frequency: different assessments, so the comparison above is illustrative only.

WHAT TO WRITE INSTEAD

"Flicker-free" is not a standardized compliance claim

4	0	4
bodies publish TLM methods	single pass/fail for the phrase	values the clause asks for

publish the measurable values, not the adjective

Multiple standards and technical documents define metrics, measurement methods or recommended limits. None turns the marketing phrase into a single standardized pass or fail claim. [2][13][15]

A PROJECT REQUIREMENT THAT CAN BE ENFORCED

Percent amplitude modulation and its dominant modulation frequency, or frequencies, shall be reported for the complete luminaire with its actual driver and control device, at 100%, 50%, 20% and minimum output, at rated input voltage on a 60 Hz supply. PstLM shall not exceed 1.0 and SVM shall not exceed 0.4 at every measured point, measured per IEC TR 61547-1 and IEC TR 63158 respectively.

These limits are adopted here as project requirements, not as pass or fail limits set by the measurement-method documents. The next step, for NLC as for the market, is to publish measured TLM values alongside the term.

SOURCES

Where every number in this deck comes from

[1] IEEE Std 1789-2015, cl. 8.1 (Inactive-Reserved 2026)
[2] CIE TN 006:2016, time-modulated lighting, SVM
[3] IEC TR 61547-1, PstLM flickermeter method, no limit
[4] Regulation (EU) 2019/2020 Annex II, amended 2021/341
[5] 2025 California Energy Code, JA8 and JA10
[6] WELL v2 Feature L08 Part 2
[7] California IOUs, LED flicker tests, TN 208928, 2016
[8] DOE CALiPER Retail Lamps Study 3.1, PNNL-23944, 2014
[9] Saudi Arabian Grid Code cl. 2.4.2.1 and 2.4.6.2
[10] SASO 2870, 2902:2018, 2927:2019, as reviewed
[11] FIFA Lighting Guide v2020.01, cl. 1.55 and 1.51
[12] DOE CALiPER Report 20.2, PNNL-SA-23263, 2014
[13] IEC TR 63158:2018, SVM measurement method
[14] CIE TN 012:2021, measuring temporal light modulation
[15] ANSI/NEMA C82.77-6-2023, Temporal Light Artifacts

Figures on slides 3, 4, 5, 7, 10 and 12 are computed from the cited equations, not traced.

PRACTICAL LIGHTING ENGINEERING

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