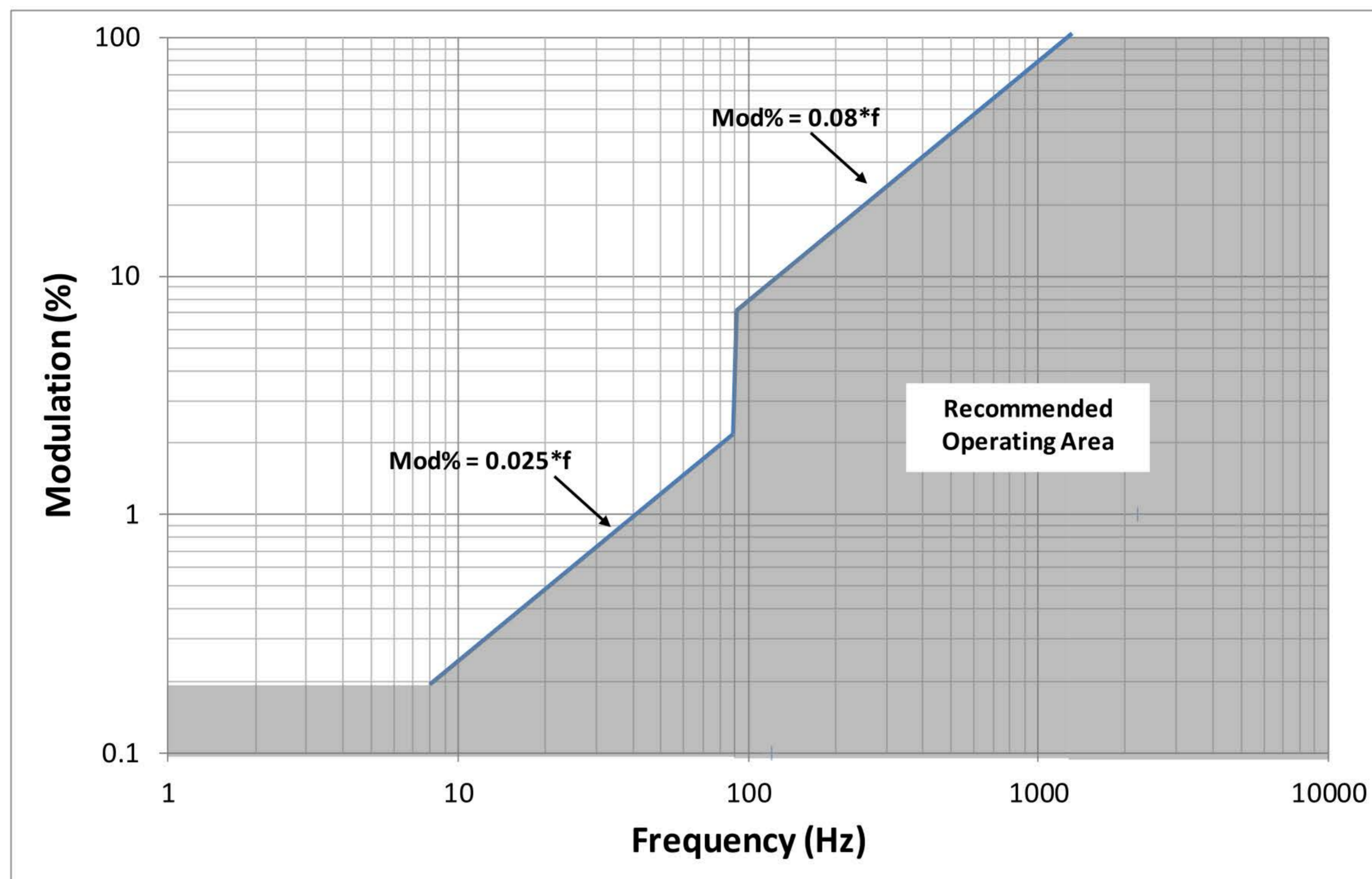


# IEEE Recommended Practices for Modulating Current in High-Brightness LEDs for Mitigating Health Risks to Viewers

IEEE Power Electronics Society

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NOTE—Operating in the shaded area minimizes visual discomfort or annoyance and also gives low risk for headaches and photosensitive epileptic seizures. Below 90 Hz, Modulation (%) is less than  $0.025 \times \text{frequency}$ . At or above 90 Hz, Modulation (%) is below  $0.08 \times \text{frequency}$ . Modulation (%) =  $100 \times (L_{max} - L_{min}) / (L_{max} + L_{min})$  where  $L_{max}$ , and  $L_{min}$  correspond to the maximum and minimum luminance, respectively. The figure was derived from the low-risk regions in Figure 18.

**Figure 20—Recommended practices summary<sup>13</sup>**

### 8.1.1 Simple recommended practices

Assume perfect ac power line conditions (purely sinusoidal with constant frequency and constant peak voltage). To limit the biological effects and detection of flicker in general illumination, then the Modulation (%) should be kept within the shaded region in Figure 20.

Specifically, define

$$\text{Modulation (\%)} = \text{Mod\%} = 100 \times (L_{max} - L_{min}) / (L_{max} + L_{min})$$

where  $L_{max}$  and  $L_{min}$  correspond to the maximum and minimum luminance, respectively. Then flicker Modulation (%) can be kept in the following regions for limited biological effects:

- **Recommended Practice 1:** If it is desired to limit the possible adverse biological effects of flicker, then flicker Modulation (%) should satisfy the following goals:
  - Below 90 Hz, Modulation (%) is less than  $0.025 \times \text{frequency}$ .
  - Between 90 Hz and 1250 Hz, Modulation (%) is below  $0.08 \times \text{frequency}$ .
  - Above 1250 Hz, there is no restriction on Modulation (%).

- **Recommended Practice 2:** If it is desired to operate within the recommended NOEL of flicker, then flicker Modulation (%) should be reduced by 2.5 times below the limited biological effect level given in Recommended Practice 1:
  - Below 90 Hz, Modulation (%) is less than  $0.01 \times \text{frequency}$ .
  - Between 90 Hz and 3000 Hz, Modulation (%) is below  $0.0333 \times \text{frequency}$ .
  - Above 3000 Hz, there is no restriction on Modulation (%).

- **Recommended Practice 3: (seizure prevention)** For any lighting source, under all operating scenarios, flicker Modulation (%) shall satisfy the following goal:
  - Below 90 Hz, Modulation (%) is less than 5%.

#### 8.1.1.1 Comment 1

The recommended practices should be adhered to in all operating conditions, that is, in normal operation as well as failure modes, such as end-of-life scenarios, improper operation with dimmer switches, and all other operating circumstances. Furthermore, the authors of this document are unaware of widespread LED driving methods that insert harmonics below twice the line frequency, at least under normal operation. Therefore, it seems reasonable to give a general guideline to avoid flicker below 90 Hz whenever possible, in addition to Recommended Practice 2 and Recommended Practice 3.

#### 8.1.1.2 Comment 2

As discussed in Clause 7, the distribution of light flicker characteristics among LED lights that will populate the future marketplace is unknown. There is no innate flicker hazard in LED lighting. However, it is assumed here that flicker characteristics of future LED lights could be uncontrolled and that nearly all of the U.S. population will be exposed to a potentially hazardous condition created by flicker at least once during a one-year timespan. Therefore, IEEE Std 1789 does not make application-specific recommended practices that are different for each lighting scenario.<sup>13</sup> Instead, Recommended Practice 1 and Recommended Practice 2 begin with the phrase “If it is desired.” However, these important issues must be analyzed by lighting designers, and such issues are presented in 8.5. On the other hand, Recommended Practice 3 is a strict rule for seizure prevention and should be adhered to at all times for all operating conditions. This recommended practice does not begin with the phrase “If it is desired.”

#### 8.1.1.3 Comment 3

The recommended practices describe the boundary functions of operation for the entire LED light source and not for the individual modulation of a single LED within the light source. It is well known that light can be phased and properly diffused so that the resultant total light source has a much lower net light output modulation. Alternatively, the flickering light source may be combined with daylight or other non-flickering sources to create lighting that flickers less.

### 8.1.2 Example calculations

Normally in lighting, the flicker frequency will have a fundamental component at twice the ac line frequency, i.e.,  $f_{Flicker} = 2 \times f_{ac}$  and that  $f_{Flicker} > CFF$ . Then, applying Figure 20 and the recommended practices, it is recommended that

$$\begin{aligned} Mod\% &< 0.08 \times f_{Flicker} \text{ for Low-Risk Level} \\ Mod\% &< 0.0333 \times f_{Flicker} \text{ for NOEL} \end{aligned}$$

#### 8.1.2.1 Example 1: USA $f_{ac} = 60$ Hz

The Recommended Practice 1 for Low-Risk Level leads to Modulation (%) satisfying  $Mod\% < 0.08 \times 120 \text{ Hz} = 10\%$  (rounded to the nearest percent).